OPERATING INSTRUCTIONS

# TYPE 1607-A

# TRANSFER-FUNCTION AND IMMITTANCE BRIDGE

1607-A

GENERAL RADIO COMPANY

E

OPERATING INSTRUCTIONS

# TYPE 1607-A

# TRANSFER-FUNCTION AND IMMITTANCE BRIDGE

Form 1607-0100-E
July, 1963

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GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

# SPECIFICATIONS

**Frequency Range:** 25-1500 Mc, with reduced accuracy above 1000 Mc and when flexible line-extension cables (required below 150 Mc) are used.

**Measurement Ranges and Accuracy:** See table below.

**DC Bias:** Terminals are provided for external dc bias. Maximum bias current, 2.5 amperes, continuous higher currents are permissible for short periods; maximum bias voltage, 400 volts.

**Accessories Supplied:** Refer to paragraph 1.3.

**Accessories Required:** Generator, detector, and mount. Unit Oscillators and Type DNT Detectors are recommended. Refer to paragraph 1.3 for list of tube mounts, to table at rear of manual for list of coaxial adaptors and other accessories.

**Case:** The instrument, with accessories, is mounted in a wooden carrying and storage case.

**Dimensions (case):** 11¼ by 14½ by 40 in. (290 by 370 by 1020 mm).

**Net Weight:** 63 lb (29 kg).

| | Range | Accuracy (25 to 1000 Mc)* |
|---|---|---|
| Voltage and Current Ratios (R) | 0-30 | $2.5\ (1 + \sqrt{R})\ \% + 0.025$ ** |
| Transimpedance ($Z_{21}$) | 0-1500 ohms | $2.5\left(1 + \sqrt{\frac{Z_{21}}{50}}\right)\% + 1.25$ ohms ** |
| Transadmittance ($Y_{21}$) | 0-600 mmhos | $2.5\left(1 + \sqrt{\frac{Y_{21}}{20}}\right)\% + 0.5$ mmho ** |
| Impedance ($Z_{11}$) | 0-1000 ohms | $2.0\left(1 + \sqrt{\frac{Z_{11}}{50}}\right)\% + 1.0$ ohm ** |
| Admittance ($Y_{11}$) | 0-400 mmhos | $2.0\left(1 + \sqrt{\frac{Y_{11}}{20}}\right)\% + 0.4$ mmho ** |

* For Susceptance Standard, set according to paragraph 3.1.3.

** When a Type 1607-P10 or -P11 Multiplier Plate is used, these residual errors are significantly reduced.

U. S. Patent No. 2,548,457.

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## TYPICAL QUANTITIES MEASURED WITH THE TYPE 1607-A TRANSFER-FUNCTION AND IMMITTANCE BRIDGE

| TRANSISTORS | VACUUM TUBES | THREE- AND FOUR-TERMINAL NETWORKS | DIODES | LUMPED COMPONENTS | COAXIAL LINES |
|---|---|---|---|---|---|
| $\alpha$, $\beta$, $h_f$, $h_r$, $h_i$, $h_o$, $r'_b$, all short-circuit admittance and open-circuit impedance parameters. | $Y_m$ ($Y_{21}$), $Y_{12}$, $Y_{11}$, $Y_{22}$, $\mu$, etc. | $Z_{11}$, $Z_{22}$, $Z_{21}$, $Z_{12}$, $Y_{11}$, $Y_{22}$, $Y_{21}$, $Y_{12}$, $I_2/I_1$, $I_1/I_2$, $E_2/E_1$, $E_1/E_2$ | Z, Y, R, C | R, L, C | Z, VSWR, Y, $\lvert\rho\rvert$ |

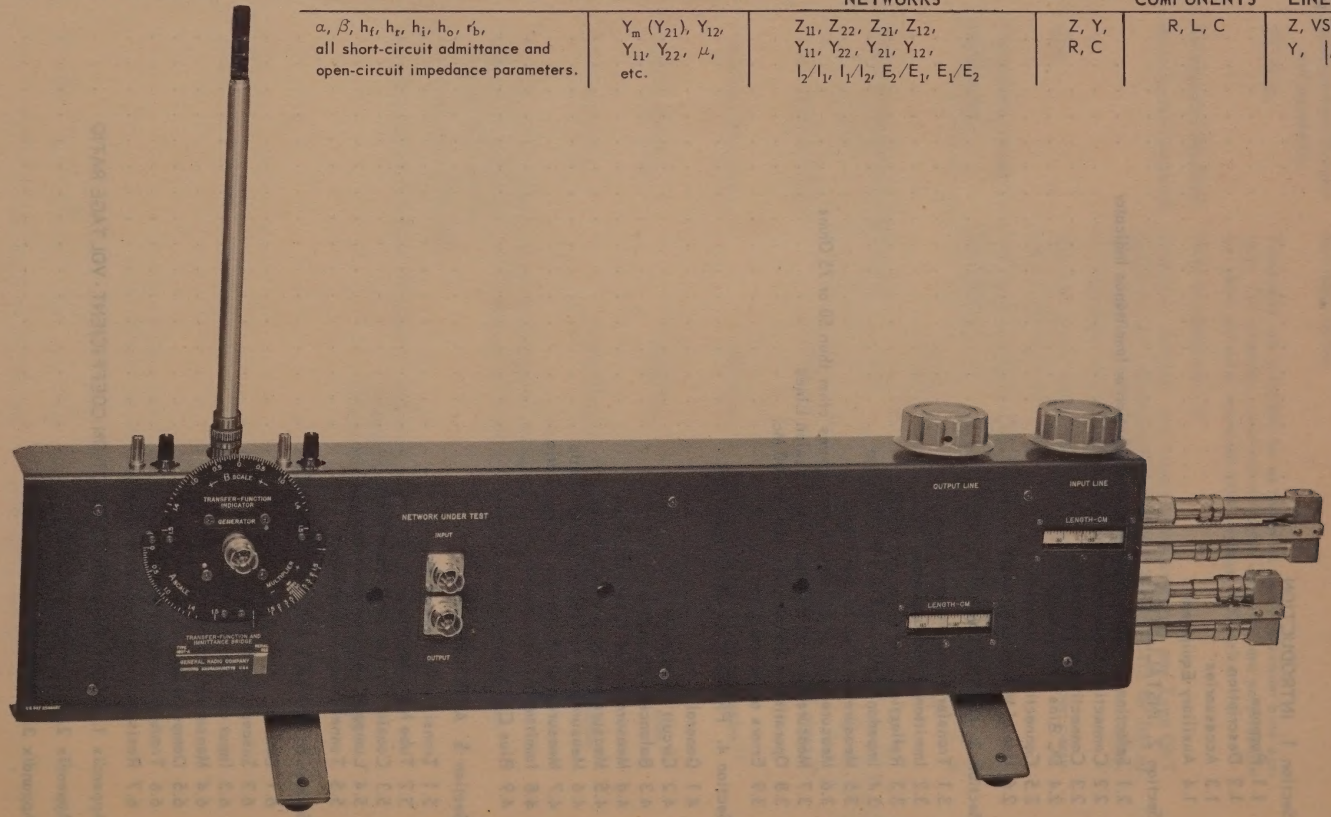



Figure 1. Type 1607-A Transfer-Function and Immittance Bridge.

# TYPE 1607-A
# TRANSFER-FUNCTION AND IMMITTANCE BRIDGE

## Section 1
## INTRODUCTION

1.1 PURPOSE. The Type 1607-A Transfer-Function and Immittance Bridge (Figure 1) is a null-type instrument designed for the measurement of:

Transadmittance
Transimpedance
Transfer Current Ratio
Transfer Voltage Ratio
Input and Output Impedance
Input and Output Admittance
Hybrid Parameters
Reflection Coefficient
Standing-Wave Ratio

from 25 to 1500 megacycles, with reduced accuracy above 1000 megacycles. Measurements can be made on active as well as passive elements, such as vacuum tubes and transistors. The uses of the instrument may be roughly divided into transfer-function and immittance (i. e., admittance or impedance) measurements. A separate indicator unit is supplied for each of these two broad classifications, and scales are calibrated in normalized numbers since they are called on to indicate various units.

With the Transfer-Function Indicator in place, the instrument will measure transadmittance, transimpedance, transfer current ratio, and transfer voltage ratio. It will also measure the direct (ungrounded) impedance or admittance of components by treating them as three-terminal networks.

With the Immittance Indicator in place, the instrument will measure the input or output impedance or admittance of four-terminal networks with the network terminated in either a short or open circuit. It will also measure the two-terminal (grounded) admittance or impedance of components and the reflection coefficient and VSWR of antennas and transmission lines.

1.2 DESCRIPTION. The basic functional components of the Transfer-Function and Immittance Bridge are: a junction block to which are connected standards and adjustable lines, an indicator assembly (either transfer-function or immittance) with coupling loops and balancing controls, and two adjustable, trombone-type coaxial lines.

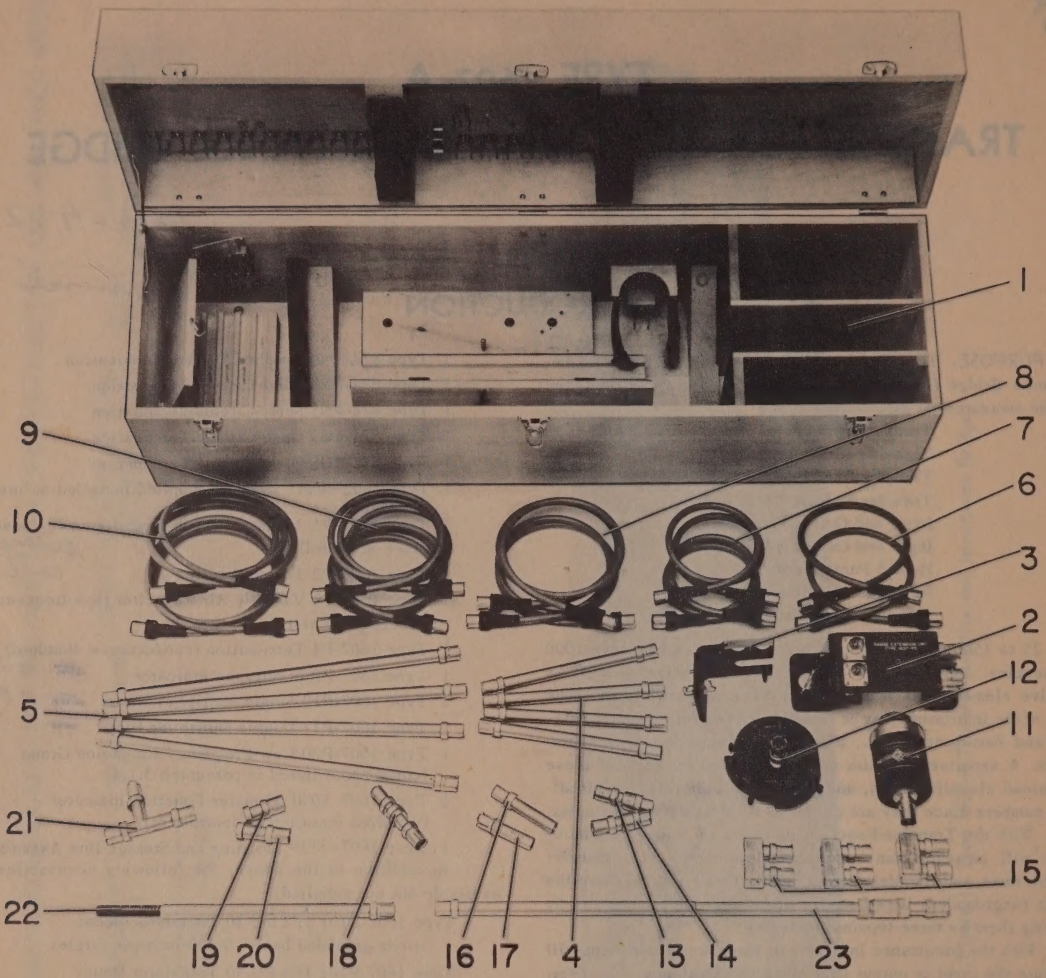
1.3 ACCESSORIES. The following accessories are supplied with the Transfer-Function and Immittance Bridge (see Figure 2):

1 Type 874-G10 10-db Fixed Attenuator
1 Type 874-LK20L Adjustable Line
3 Type 874-U U-Line Sections
1 Type 874-W50 Matched 50-ohm Termination
1 Type 874-WN3 Short-Circuit Termination
1 Type 874-WN5 Short-Circuit Termination
1 Type 874-WO3 Open-Circuit Termination
1 Type 874-WO5 Open-Circuit Termination
1 Type 1602-0940 Gasket (supplied installed on instrument)
1 Type 1607-P1 Adjustable Stub (high-frequency susceptance standard)
1 Type 1607-P2 Tee Assembly
1 Type 1607-P3 Variable Air Capacitor (low-frequency susceptance standard)
1 Type 1607-P4 Termination (conductance standard)
1 Type 1607-P9 Immittance Indicator
1 Type 1607-P10 Single Multiplier Plate
1 Type 1607-P11 Double Multiplier Plate
1 Type 1607-P20 Low-Frequency Extension Group (components listed in paragraph 3.1.4)
1 Type 1607-3030 Transfer-Function Indicator (supplied installed on instrument)
1 Type 1607-3130 Shipping and Storage Box Assembly

In addition to the above, the following accessories are available but not supplied:

Type 1607-P101 JETEC-30 Transistor Mount (triode grounded base - 0.200-inch pin circle)
Type 1607-P102 JETEC-30 Transistor Mount (triode grounded emitter - 0.200-inch pin circle)
Type 1607-P111 JETEC Transistor Mount (triode grounded base - 0.100-inch pin circle)
Type 1607-P201 Tube Mount (7-pin miniature, grounded cathode, for 6AF4, 6AF4A, 6AN4, 6T4, and other tubes with same pin connections)
Type 1607-P401 JETEC Transistor Tetrode Mount (grounded base - 0.200-inch pin circle)
Type 1607-P601 Ungrounded Component Mount
Type 874-ML (Grounded) Component Mount

1.4 AUXILIARY EQUIPMENT. The usual measurement setup (see Figure 3) of the Transfer-Function and Immittance Bridge requires, in addition to the accessories supplied with the bridge, the use of a generator, a detector, and a mount suitable for the unknown to be measured. If the unknown requires d-c bias, a bias supply is also needed.




**LEGEND**

1. Shipping and Storage Box Assembly (1607-3130)
2. Range Extension Unit (1607-P5)
3. Support Bracket Unit (1607-P6)
4. 21.5-cm Air Lines (1607-P7-△/2)
5. 43-cm Air Lines (1607-P7-△)
6. Patch Cords (1607-P8-2△)
7. Patch Cords (1607-P8-3△)
8. Patch Cords (1607-P8-4△)
9. Patch Cords (1607-P8-5△)
10. Patch Cords (1607-P8-6△)
11. Variable Air Capacitor (1607-P3)
12. Immittance Indicator (1607-P9)
13. Termination (1607-P4)
14. Matched 50Ω Termination (874-W50)
15. U-Line Sections (874-U)
16. Open-Circuit Termination (874-WO5)
17. Open-Circuit Termination (874-WO3)
18. 10-db Attenuator Pad (874-G10)
19. Short-Circuit Termination (874-WN3)
20. Short-Circuit Termination (874-WN5)
21. Tee Assembly (1607-P2)
22. Adjustable Stub (1607-P1)
23. Adjustable Air Line (874-LK20L)

Not Shown: Main instrument, with Transfer-Function Indicator (1607-3030)
Multiplier Plates (1607-P10 and -P11)
Gasket (1602-0940)

Figure 2. Principal Components and Accessories.

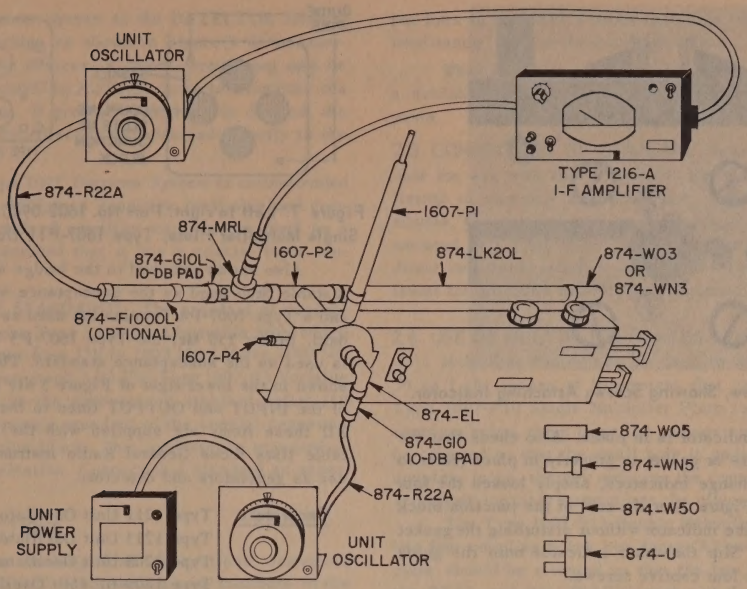



Figure 3. Typical Measurement Setup.

# Section 2
# INSTALLATION

2.1 SELECTION AND MOUNTING OF TRANSFER-FUNCTION OR IMMITTANCE INDICATOR. The Type 1607-A is normally shipped with the Transfer-Function Indicator (Figure 4) in place. Immittance measurements usually require the use of the Immittance Indicator (Figure 5). Before beginning any measurement, check the operating instructions for that measurement to make

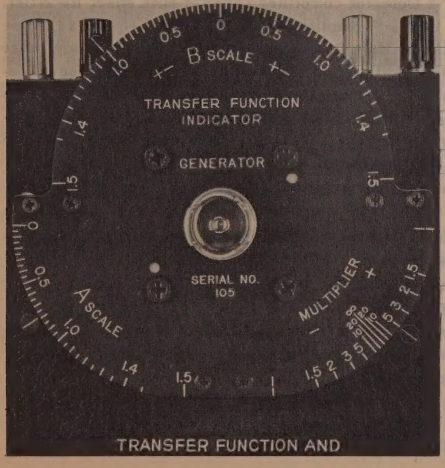



Figure 4.
Transfer-Function Indicator.

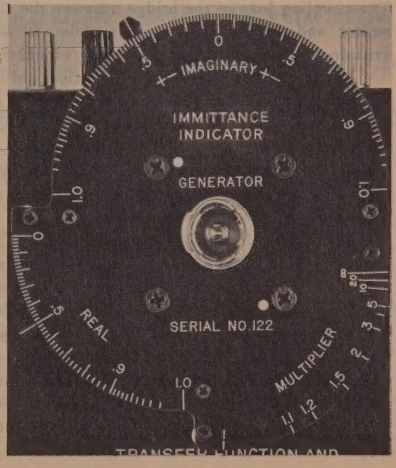



Figure 5.
Immittance Indicator.

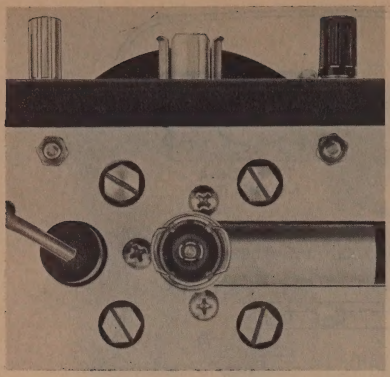


Figure 6. Rear View, Showing Screws Attaching Indicator.

sure that the proper indicator is in place. Also check that the desired multiplier plate or gasket is properly in place (refer to paragraph 2.6). To change indicators, simply loosen the four captive screws (see Figure 6) at the rear of the junction block and carefully remove the indicator without disturbing the gasket or multiplier plate. Slip the other indicator onto the guide pins and retighten the four captive screws.

The gasket (Part No. 1602-0940) shown in Figure 7 is installed in the instrument as supplied, and is left in place for most measurements. When the Type 1607-P10 or -P11 Multiplier Plate is used, the gasket should be removed (refer to paragraph 3.2.10).

2.2 CONNECTION OF GENERATOR AND DETECTOR. In the setup of Figure 3, a General Radio Unit Oscillator is connected through a Type 874-R22A Patch Cord, 10-db Pad, and Ell to the GENERATOR connector at the front of the indicator. The ell (supplied with the Type DNT Detector) is used for convenience, and the 10-db pad is used to isolate the oscillator from load changes and to keep the applied signal at a safe low value for transistor measurements. (If the sensitivity is low, and a higher level is allowable on the unknown, this pad may be removed. The coupling loss of the bridge between the GENERATOR connector and device under test is about 40 db at 500 Mc, increasing at the rate of 6 db per octave with decreasing frequency.

At the rear of the Transfer-Function and Immittance Bridge (Figure 3) are shown a Unit Oscillator (the local oscillator), I-F Amplifier and Null Detector, 10-db Pad, Type 874-MRL Mixer Rectifier, and a Type 874-F Low-Pass Filter, the whole available as the General Radio Type DNT Detector. (Below 500 Mc, the low-pass filter is usually not required, as harmonics are separated enough to avoid confusion.) Also at the rear, connected to the DETECTOR terminal, are a Type 1607-P2 Tee Assembly, Type 874-LK20L Constant-Impedance Adjustable Line, and a short- or open-circuit termination, all of which are supplied with the bridge. This last-named local-oscillator rejection-filter group is desirable in the measurement of active networks to trap out high-level local-oscillator signals lest they be too strong at the terminals of the unknown device. In the measurements of passive networks, a Type 874-W50 Termination is connected to the Type 1607-P2 in place of the Type 874-LK20L Adjustable Line (refer to paragraph 3.1.5).

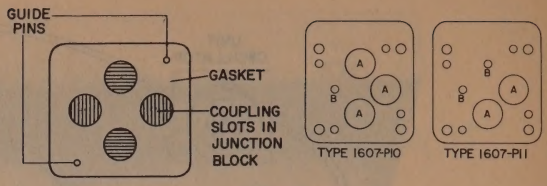



Figure 7. Left to right: Part No. 1602-0940 Gasket, Type 1607-P10 Single Multiplier Plate, Type 1607-P11 Double Multiplier Plate.

Also shown attached to the bridge are a Type 1607-P1 Adjustable Stub used as the susceptance standard above 150 Mc, and a Type 1607-P4 Termination used as the conductance standard. Below 150 Mc, the Type 1607-P3 Variable Air Capacitor is used as the susceptance standard. The various terminations shown in the lower right of Figure 3 are used in the adjustment of the INPUT and OUTPUT lines to their appropriate lengths. All these items are supplied with the bridge. The following table lists those General Radio instruments recommended for use as generators and detectors.

| | |
|---|---|
| Generators | Type 1211 Unit Oscillator - 0.5 - 50 Mc |
| | Type 1215 Unit Oscillator - 50 - 250 Mc |
| | Type 1208 Unit Oscillator - 65 - 500 Mc |
| | Type 1209-BL Unit Oscillator - 180 - 600 Mc |
| | Type 1209-B Unit Oscillator - 250 - 920 Mc |
| | Type 1218 Unit Oscillator - 900 - 2000 Mc |
| Power Supplies (for above Unit Oscillators) | |
| | Type 1203 Unit Power Supply |
| | Type 1201 Unit Regulated Power Supply |
| Detectors* | Type DNT-1 Detector - 40 - 530 Mc |
| | Type DNT-2 Detector - 40 - 280 Mc |
| | Type DNT-3 Detector - 220 - 950 Mc |
| | Type DNT-4 Detector - 870 - 2030 Mc |
| | Type 1216 Unit I-F Amplifier - 30 Mc only |
| | Communication Receivers - below 40 Mc |

*Type DNT-1 Detector comprises Type 874-MRL Mixer Rectifier, Type 1216 Unit I-F Amplifier, Type 874-G10L 10-db Pad, Type 874-EL-L Ell, and Unit Oscillator and filter for frequency range desired (Unit Oscillator is powered by Type 1216). Use of oscillator harmonics extends frequency range considerably, but is not recommended for measurements on nonlinear devices. Frequency range of any DNT Detector can be extended by addition of suitable Unit Oscillator and filter.

The following equipment comprises a complete detector system for the 40 - 2030-Mc range (and 30 Mc):

Type DNT-3 Detector, including:
- Type 874-MRL Mixer Rectifier
- Type 1216-A Unit I-F Amplifier
- Type 874-G10L 10-db Pad
- Type 874-EL-L Ell
- Type 1209-B Unit Oscillator (220 - 950 Mc)
- Type 874-F1000L Filter

Type 1215-B Unit Oscillator (40 - 280 Mc)
Type 1218-A Unit Oscillator (870 - 2030 Mc)
Type 874-F2000L Filter

Connect the detector system to the DETECTOR connector at the rear of the bridge as shown in Figure 3. In measurements on strictly linear devices, a direct termination may be substituted for the Type 874-LK20L Air Line to eliminate the need of tuning this line. If greater sensitivity is desired, the Type 874-MRL Mixer Rectifier can be connected directly to the DETECTOR terminals.

Although the Type DNT Detector System is recommended for use with the Type 1607-A, a sensitive, well-shielded communications receiver with r-f amplifier can also be used as a heterodyne detector, provided that it has a coaxial input connector.

2.3 CONNECTION OF STANDARDS. The standard of susceptance above 150 Mc is the Type 1607-P1 Adjustable Stub, which is calibrated in frequency from 150 to 1000 Mc. (Above 1000 Mc, set it as described in paragraph 3.8.) The Type 1607-P3 Variable Air Capacitor is used as the susceptance standard below 150 Mc. Connect the susceptance standard to the coaxial connector at the top of the junction block. The conductance standard is the Type 1607-P4 Termination. Connect this standard as shown in Figure 3.

2.4 DC BIAS CONNECTIONS.

2.4.1 GENERAL. When making bias connections, remember that the high (black) INPUT BIAS binding post connects to the center conductor of the NETWORK UNDER TEST INPUT connector and that the high (black) OUTPUT BIAS binding post connects to the center conductor of the NETWORK OUTPUT connector. Also remember that bias connections must be reversed for immittance measurements and for measurements of reverse parameters with the unknown connections reversed ($I_{max}$ = 2.5 amps; $E_{max}$ = 400 v ).

2.4.2 TRANSFER-FUNCTION MEASUREMENTS. In forward transfer-function measurements, dc input bias should be applied at the INPUT BIAS terminals, output bias at the OUTPUT BIAS terminals. Reverse transfer-function measurements, of course, require these connections to be reversed.

Normally, biases should not be turned on until after connection of the network under test. After the network is inserted, energize the bias supply according to the requirements of the network. With transistors, for instance, the collector voltage should normally be turned on first and emitter current then increased from zero to the required value. With vacuum tubes it is usually best to establish the grid bias first and then to turn on the other voltages.

2.4.3 IMMITTANCE MEASUREMENTS. In measurements of the direct immittance of ungrounded components (i. e., by treating them as three-terminal networks), dc bias should be applied between the high INPUT BIAS and high OUTPUT BIAS binding posts, since the ungrounded component is connected between the two NETWORK UNDER TEST center conductors.

When measuring input immittance of four-terminal networks, connect the input bias to the OUTPUT BIAS terminals and output bias to the INPUT BIAS terminals. When measuring output immittance, reverse these connections.

When measuring the grounded, two-terminal immittance of a nonlinear device, apply bias to the OUTPUT BIAS binding posts.

2.5 CONNECTION OF UNKNOWN. Several mounts are available for use with the instrument. Refer to paragraph 1.3 for a listing of currently available tube, transistor, and component mounts. Components such as resistors, capacitors, etc., can be mounted in a Type 1607-P601 Component Mount for ungrounded direct immittance measurements, or in a Type 874-ML Component Mount for grounded two-terminal immittance measurements.

2.6 USE OF MULTIPLIER PLATES. The Types 1607-P10 and -P11 Multiplier Plates can be used to increase by a factor of 10 to 1 the ranges of parameters that can be measured. The Type 1607-P10 Single Multiplier Plate (see Figure 7) has four coupling holes, three large (A) and one small (B). The plate can be oriented so that the small hole is under any one of the three coupling loops, thereby reducing the coupling to that loop. The accompanying table summarizes the effect obtained in each case.

The Type 1607-P11 Double Multiplier Plate (see Figure 7) has four coupling holes, two large (A) and two small (B). This plate should be oriented so that the two small holes are under the REAL and IMAGINARY (or A and B) loops. The effect on scale readings is shown in the accompanying table.

| Position of Small Coupling Hole(s) | Multiplying Factor | |
|---|---|---|
| | Scale | Multiply by |
| 1607-P10 Plate | | |
| G | A or REAL* | 0.1 |
| B | B or IMAG* | 0.1 |
| $M_I$ or $M_{TF}$* | MULTIPLIER | 10 |
| 1607-P11 Plate | | |
| G & B | MULTIPLIER | 0.1 |

Effect on Scale Reading Due to Use of Multiplier Plates.

*depending on indicator used ($M_I$ refers to Immittance Indicator; $M_{TF}$ refers to Transfer-Function Indicator).

To install either of the multiplier plates, proceed as follows:

a. Loosen the four captive screws (see Figure 6) at the rear of the junction block and remove the indicator head.

b. Remove the gasket and insert the multiplier plate in its place (refer to accompanying table for proper orientation).

c. Replace the indicator head and tighten the four captive screws.

NOTE

Either the gasket or one of the multiplier plates should always be in place between the indicator head and the junction block. Gaskets and multiplier plates should always be installed with bent-in lips around the large holes facing the slots in the junction block.

Use of a multiplier plate does not affect the measurement procedures given in Section 3.

# Section 3
# OPERATING PROCEDURE

## 3.1 TRANSFER-FUNCTION MEASUREMENTS.

3.1.1 GENERAL. Basically, the measurement procedure consists of these steps: adjustment of INPUT and OUTPUT LINES, adjustment of susceptance standard, trapping of local-oscillator signals (if necessary), attaching (and biasing, if necessary) the network under test, balancing the bridge, and reading the dials. Of these the first three steps need be repeated only when the frequency or parameter being measured is changed.

3.1.2 ADJUSTMENT OF INPUT AND OUTPUT LINES.

3.1.2.1 General. After generator and detector have been set to the frequencies required by the measurement (with the Type DNT Detector the local oscillator should be set 30 Mc away from the frequency of the signal source), each of the two adjustable lines must be set to either a multiple of a half wavelength or to an odd multiple of a quarter wavelength, depending on the transfer function being measured. The four basic transfer functions are given below with the line conditions necessary for measurement:

| Parameter | Input Line | Output Line |
|---|---|---|
| Transadmittance ($Y_{21}$, $Y_{12}$) | $\lambda/2$ | $\lambda/2$ |
| Transfer Voltage Ratio ($h_r$, $E_2/E_1$) | $\lambda/2$ | $\lambda/4$ |
| Transimpedance ($Z_{21}$, $Z_{12}$) | $\lambda/4$ | $\lambda/4$ |
| Transfer Current Ratio ($-\alpha$, $\beta$, $h_f$, $I_2/I_1$) | $\lambda/4$ | $\lambda/2$ |

("$\lambda/4$" above means an odd integral multiple of a quarter wavelength, and "$\lambda/2$" means an integral multiple of a half wavelength.)

At frequencies below 300 Mc, the adjustment range of the line is not sufficient to obtain multiples of $\lambda/4$ or $\lambda/2$ settings under all conditions. Figure 8 is a chart showing the frequency bands at which these settings can be obtained. The desired line length can be obtained by the addition of additional lengths of air line or cable provided with the bridge. The adjustment ranges with various lengths of additional line are also shown on the chart. The length increments are shown in terms of the quantity "$\Delta$", which is actually 43 centimeters, or slightly less than the adjustment range of the internal lines. The table below shows the "$\Delta$" lengths of the various Type 1607 coaxial line components and accessories.

NOTE

The INPUT and OUTPUT LINE scales are calibrated in cm, representing the distance between the center of the coupling loop and the reference plane used in the measurement (refer to NOTE in paragraph 3.1.2.2). The scale calibration is based on the reference plane produced by Type 874-WN5 and -WO5 Terminations (see Figure 9). When the Range Extension Unit is used, the scale indication must be increased by 43 cm for each $\Delta$. The Range Extension Unit with U-Blocks adds one $\Delta$; if cables are used and the U-Blocks omitted, the extension unit adds $\frac{3}{4}\Delta$.

To adjust the lines correctly, first adjust the OUTPUT LINE to the condition demanded of the INPUT LINE (e. g., for transfer-current-ratio measurements first set the OUTPUT LINE to $\lambda/4$). Then the INPUT LINE can also be set to this electrical length. Finally, the OUTPUT LINE can be reset to its proper length if it differs from that of the INPUT LINE. Thus to adjust the lines for a transfer-voltage-ratio measurement (INPUT $\lambda/2$, OUTPUT $\lambda/4$), first set the OUTPUT LINE to $\lambda/2$, then set the INPUT LINE to $\lambda/2$, and finally set the OUTPUT LINE to $\lambda/4$.

For maximum accuracy in immittance measurements, the standing-wave pattern on the OUTPUT LINE should be approximately the same during setup as during measurement. For this reason, alternate setup procedures are given for high- and low-impedance (admittance) measurements in Section 3.2.

All dc bias supplies must be turned off while line adjustments are being made.

3.1.2.2 Adjustment of OUTPUT LINE to Half Wavelength.

a. Set the susceptance standard to the frequency of measurement.

b. Carefully set the MULTIPLIER arm to $\infty$.

Table showing combinations of accessories recommended to obtain the various line-length extensions listed in left-hand column. Other columns indicate items required for a particular line-length extension. Numbers at top of each column give length of each item in terms of $\Delta$.

| | RANGE EXT. UNIT | U-BLOCK | AIR LINES | | CABLES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1607-P5 $\frac{3}{4}\Delta$ | 874-U $\frac{1}{4}\Delta$ | 1607-P7 $\Delta/2$ | 1607-P7 $\Delta$ | 1607-P8 $2\Delta$ | 1607-P8 $3\Delta$ | 1607-P8 $4\Delta$ | 1607-P8 $5\Delta$ | 1607-P8 $6\Delta$ |
| $1\Delta$ | 1 | 1 | | | | | | | |
| $2\Delta$ | 1 | 1 | 2 | | | | | | |
| $3\Delta$ | 1 | 1 | | 2 | | | | | |
| $4\Delta$ | 1 | 1 | 2 | 2 | | | | | |
| $4\frac{3}{4}\Delta$ | 1 | | | 2 | 1 | | | | |
| $5\frac{3}{4}\Delta$ | 1 | | | 2 | | 1 | | | |
| $6\frac{3}{4}\Delta$ | 1 | | | 2 | | | 1 | | |
| $7\frac{3}{4}\Delta$ | 1 | | | 2 | | | | 1 | |
| $8\frac{3}{4}\Delta$ | 1 | | | 2 | | | | | 1 |
| $9\frac{3}{4}\Delta$ | 1 | | | 2 | 1 | | | 1 | |

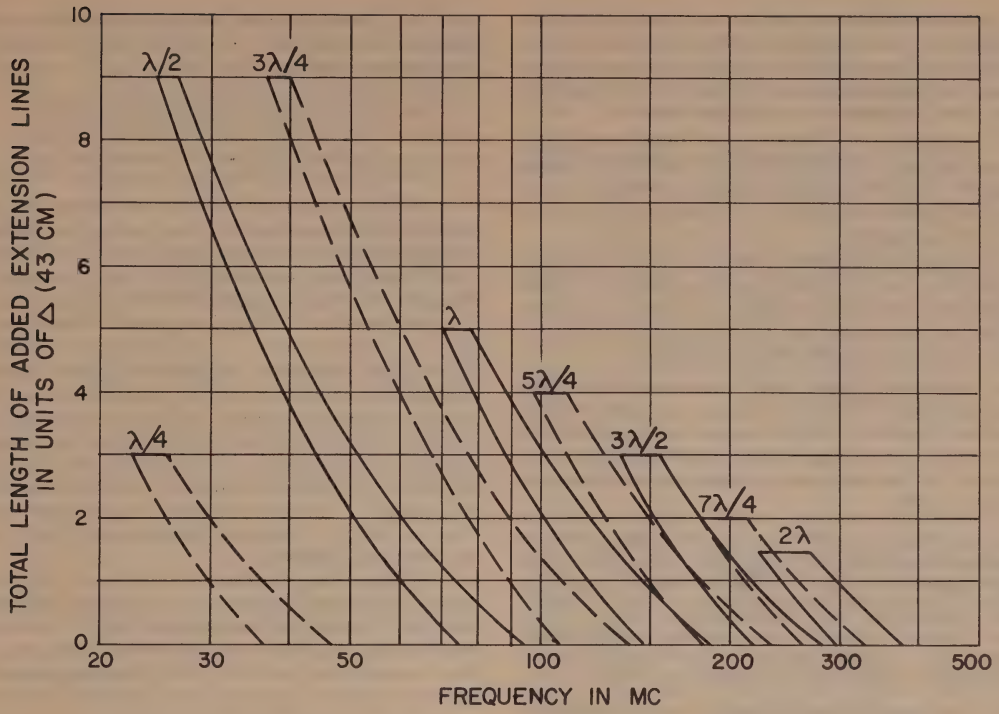



Figure 8. Required Line Lengths for Low-Frequency Operation.

c. Set the A arm to full scale and the B arm to 0.

d. At frequencies below 300 Mc, install range extension unit and additional line lengths if necessary. (Refer to paragraph 3.1.2.1, paragraph 3.1.4, and Figure 8.)

e. Plug the Type 874-WN5 Short-Circuit Termination into the OUTPUT CONNECTOR and adjust the OUTPUT LINE until the detector registers a deep minimum (a complete null will not be obtained because of losses in the lines). Since a slight false minimum may sometimes occur because of interaction at the local-oscillator frequency, be sure to obtain a deep minimum. If the mixer is connected directly to the instrument as described in paragraph 3.1.5, the false minimum may be very deep. To check for a false null, switch the Type 1216-A I-F Amplifier to indicate rectified mixer current and observe the variation of mixer current near the line setting at which the null was obtained. If the mixer current has a deep minimum in this vicinity, the lines are probably set incorrectly. Another way of checking for false minimum is to check the total line length in cm (refer to paragraph 3.1.2.1) against the known wavelength ($\lambda cm = \frac{30,000}{f_{Mc}}$). Also, the insertion of a pad between the instrument and the mixer usually eliminates the effect.

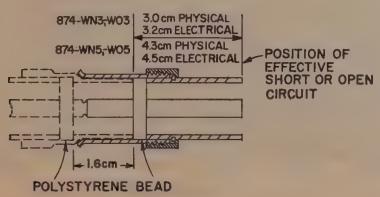



Figure 9. Cross-Section of Type 874-WN3, -WN5 and -WO3, -WO5 Terminations, Showing Reference Plane.

NOTE

The references to the Type 874-WN5 and Type 874-WO5 Terminations presuppose the use of standard tube and transistor mounts with the Transfer-Function and Immittance Bridge. These mounts have reference planes 4.5cm from the connectors (see Figure 9), and the 4.5cm short and open circuits are therefore called for. If a nonstandard accessory with different line lengths is used, special short and open circuits should be constructed, or the difference between its spacing and that of the Type 874-WN5 and -WO5 can be corrected for by changing the settings of the adjustable INPUT and OUTPUT LINES. The amount of correction can be determined by means of the line length scales on the bridge. For instance, if a mount with 8-cm electrical spacing to the reference plane were used, the Types 874-WN5 and 874-WO5 could still be used, provided the INPUT and OUTPUT LINES were shortened by 3.5 cm after all other line-length adjustments had been made.

In immittance measurements, the final setting of the OUTPUT LINE (i.e., after the INPUT LINE has been set) is sometimes made by an alternate procedure, so that the standing-wave pattern on the lines during setup will simulate that during measurement. The procedures are given in Section 3.2.

3.1.2.3 Adjustment of OUTPUT LINE to Quarter Wavelength. To adjust the OUTPUT LINE to an odd multiple of a quarter wavelength, follow the procedure in paragraph 3.1.2.2, except use a Type 874-WO5 Open-Circuit Termination in place of the short-circuit termination.

In immittance measurements, the final setting of the OUTPUT LINE (i.e., after the INPUT LINE has been set) is sometimes made by an alternate procedure, so that the standing-wave pattern on the lines during setup will simulate that during measurement. The procedures are given in Section 3.2.

3.1.2.4 Adjustment of INPUT LINE. After the OUTPUT LINE has been adjusted to the condition required of the INPUT LINE, connect the Type 874-U U-Block between the INPUT and OUTPUT connectors and adjust the INPUT LINE to give a deep minimum at the detector at approximately the same setting as the OUTPUT LINE.

NOTE: If a standard mount is not used, the length of line between the actual point of measurement and the front face of the connector plugged into the INPUT terminals must be compensated for. This electrical length is 4.5 cm in the Type 874-WN5 and -WO5 terminations. The electrical length of the Type 874-U is 9 cm. Therefore, unless the reference plane on the unknown is electrically 4.5 cm from the beads on both input and output lines, both line lengths must be changed after normal setting.

3.1.2.5 Line-Length Calibration Charts. Considerable time can be saved in measurements at different frequencies through the use of a line-length calibration chart. Such a chart would list, for each frequency desired, INPUT and OUTPUT LINE settings for the quarter- and half-wave conditions. Since the line-length settings depend on the generator frequency, for maximum accuracy the generator frequency must be accurately known, or else the same generator should be used for all measurements. A sample form for such a chart is enclosed with this manual.

3.1.3 SUSCEPTANCE STANDARD. The susceptance standard should be set to the correct frequency as indicated on its scale. If the generator frequency is in doubt or is between 1000 and 1500 Mc, or if the maximum accuracy is desired, proceed as follows: *

a. Plug the Type 874-W50 Matched Termination into the OUTPUT connector, and set the i-f amplifier for a linear mode of operation (not AVC and not overloaded).

b. Set the MULTIPLIER to ∞, and adjust the susceptance standard so that the detector indication with the B arm at ±1.5 and the A arm at zero equals the indication with the A arm at 1.5 and the B arm at zero. (With Immittance Indicator, set the REAL and IMAGINARY arms to 1.0). This procedure should yield a frequency indication on the calibrated scale nearly equal to that of the signal frequency (or 1/5 the signal frequency above 1000 Mc).

3.1.4 OPERATION WITH LOW-FREQUENCY EXTENSION LINES. The Type 1607-P20 Low-Frequency Extension Group is included with the Transfer-Function and Immittance Bridge to permit operation below 300 Mc. The Low-Frequency Extension Group comprises the following, shown in Figure 2:

1 Type 1607-P5 Range Extension Unit
1 Type 1607-P6 Support Bracket Unit
4 Type 1607-P7 Δ/2 Air Lines 21.5 cm
4 Type 1607-P7 Δ Air Lines 43 cm
2 each Types 1607-P8-2, -3, -4, -5, & -6 Δ Patch Cords

The Range Extension Unit connects directly to the INPUT and OUTPUT connectors and is secured by two quarter-turn, wing-nut fasteners. Combinations of the air lines and cables listed above can be connected to the Range Extension Unit to increase the effective length of INPUT and OUTPUT LINES. The electrical lengths of these air lines and cables are multiples of a standard length, Δ. For line-length additions up to 4Δ, air lines connected by a Type 874-U U-Block are preferred, because their impedance and loss characteristics are superior to those of the flexible cable. At the lower frequencies, however, it is necessary to use the flexible cables. Because the characteristic impedance of the flexible cables has a greater tolerance (±5%) than that of the rigid air lines, some reduction of accuracy can be caused by the use of the Range Extension Unit with cables. Figure 8 shows the number of deltas required as a function of frequency.

When the Range Extension Unit is added, together with a pair of Type 874-U U-Blocks, the combination adds one Δ to each line. When the air lines are added to this combination the extension is one Δ plus the Δ-total of the air lines used in each line. However, when the Type 874-U U-Blocks are omitted, such as when the flexible cables are used, the Range Extension Unit

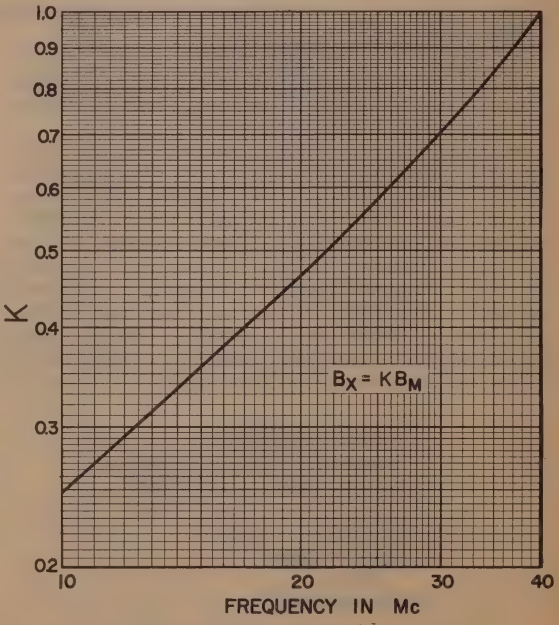



Figure 10. Correction Chart for Susceptance Standard Below 40 Mc.

*For operation below 40 Mc refer to para. 3.1.4.

contributes only three-quarters of a △ to each line.

For operation below 40 Mc, the low-frequency susceptance standard cannot be adjusted to the standard susceptance (20 mmhos). It is therefore necessary to correct the B (on Transfer-Function Indicator) or IMAGINARY (on Immittance Indicator) scale readings. Set the Type 1607-P3 Susceptance Standard to 40 Mc and multiply the B or IMAGINARY scale readings by the K factor determined from Figure 10.

Under several conditions it is probably desirable to use the flexible cables to connect to remote networks even when the extension in frequency range is not essential. This might be true where an unwieldy component is to be tested at a distance from the Transfer-Function Bridge. In such instances the ends of the cables should be considered as the INPUT and OUTPUT terminals.

3.1.5 LOCAL-OSCILLATOR TRAP. For passive networks plug the Type 874-W50 Termination into the Type 1607-P2 Tee in place of the Type 874-LK20L. If increased sensitivity is required, connect the Type 874-MR Mixer Rectifier directly to the DETECTOR terminals. (With the mixer connected directly to the DETECTOR terminals, be careful when adjusting the INPUT and OUTPUT LINES, since greater difficulty can be encountered with the false nulls mentioned in paragraph 3.1.2.2.)

If the frequency is below 350 Mc, determine from Figure 11 whether additional extension-line sections are required. Add any necessary line sections and the termination unit indicated in Figure 11. The Type 874-WN3 Short-Circuit Termination is preferred (but not required), since it attenuates all harmonics as well as the fundamental.

For active networks such as tubes and transistors, proceed as follows to "trap out" the local-oscillator signal:

a. Set the METER READS switch on the Type 1216-A I-F Amplifier to DC CRYSTAL CURRENT. Adjust the coupling of the local oscillator to give a crystal current indication between 10 and 15 percent of fullscale of the Type 1216-A meter. Return the METER READS switch to IF OUTPUT. Set A and B arms to full scale and the Multiplier arm to ∞.

b. Interchange the generator and local-oscillator connections, keeping the pads with their respective oscillators.

c. Adjust the Type 874-LK20L (connected as shown in Figure 3) to yield a minimum reading at the detector. This will require connection of either an open (Type 874-WO3) or a short (Type 874-WN3) circuit onto the adjustable line. Then tighten the locking sleeve on the Type 874-LK20L. At some frequencies, particularly those below 90 Mc, extension lines (Type 1607-P7 and -P8) must be added between the adjustable line and the termination in order to obtain proper adjustment.

d. Replace the generator and detector connections as originally connected.

e. Recheck the crystal current on the i-f amplifier. It should be between 5 and 15 percent of full scale.

3.1.6 BIAS CONNECTIONS. Connections to INPUT BIAS and OUTPUT BIAS terminals should be made, and input and output biases reduced to zero and turned off before the network under test is connected. After inserting the network, energize the bias supplies according to the requirements of measurement. Refer to paragraph 2.4.

3.1.7 BALANCE ADJUSTMENTS. Adjust the three indicator arms to obtain a null on the detector. If possible, set the MULTIPLIER to +1 or -1 and null by adjusting the A and B arms.

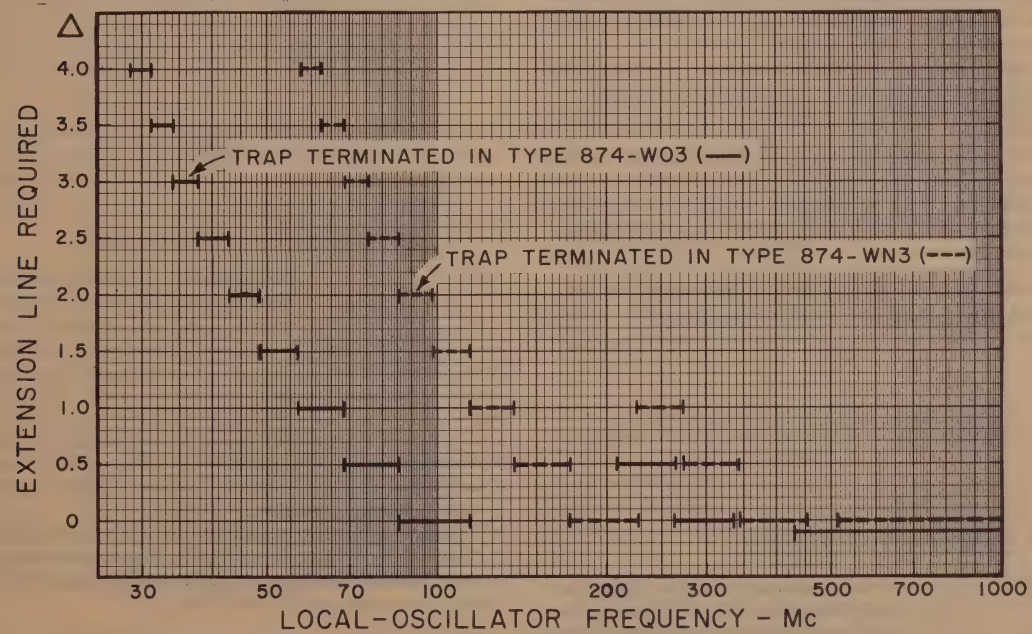



Figure 11. Required Line Lengths for Local-Oscillator Trap.

If a unity multiplier cannot be used, try successively higher multipliers until a null can be obtained by adjustment of the A and B arms.

3.1.8 PROCEDURES FOR TRANSFER-FUNCTION MEASUREMENTS.

3.1.8.1 Transadmittance ($Y_{21}$), ($I_2/E_1$).

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is active or nonlinear, trap out local-oscillator signal by reversing generator and local-oscillator connections and adjusting the trap for a null (paragraph 3.1.5). Then restore normal connections. Connect low-frequency extensions if necessary.

b. Connect Type 874-WN5 Short-Circuit Termination to OUTPUT connector, set MULTIPLIER to ∞, A arm to 1.5, B arm to 0, and adjust OUTPUT LINE for minimum detector deflection (half-wavelength condition).

c. Connect Type 874-U U-Block between INPUT and OUTPUT connectors. Adjust INPUT LINE for minimum detector deflection (half-wavelength condition; should appear at about the same setting as for OUTPUT LINE).

d. Connect the input of the network under test to INPUT, output to OUTPUT, using a suitable mount.

e. Apply biases if needed: input to INPUT BIAS, output to OUTPUT BIAS.

f. Adjust arms for null. Try first for null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. Multiply the A and B arm indications by the MULTIPLIER setting to obtain the A product and B product. (For the B indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard.)

h. The normalized transconductance is -(A product); the normalized transsusceptance is -(B product) (normalized with respect to the characteristic admittance of the 50-ohm line, 20 mmhos). *

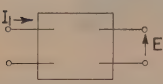
i. To obtain the transadmittance in mmhos, multiply the normalized components by 20.

j. Example: if the A indication is 0.27, the B indication -1.33, and the MULTIPLIER SETTING -1.5, the components of transadmittance are:

$G_{21}$ = -A x M x 20mmhos = -(0.27)(-1.5)(20mmhos) = 8.1mmhos

$B_{21}$ = -B x M x 20mmhos = -(-1.33)(-1.5)(20mmhos) = -j39.9mmhos

3.1.8.2 Transimpedance ($Z_{21}$), ($E_2/I_1$).




a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out local-oscillator signal by reversing generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary.

b. Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector, set MULTIPLIER to ∞, A arm to 1.5, B arm to 0, and adjust OUTPUT LINE for minimum detector deflection (quarter-wavelength condition).

c. Connect Type 874-U U-Block between INPUT and OUTPUT connectors. Adjust INPUT LINE for minimum detector deflection (quarter-wavelength condition; should appear at about the same setting as for OUTPUT LINE).

d. Connect the input of the network under test to the INPUT, output to OUTPUT, using suitable mount.

e. Apply biases if needed: input to INPUT BIAS, output to OUTPUT BIAS.

f. Adjust arms for null. Try first for null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. Multiply the A and B arm indications by the MULTIPLIER setting to obtain the A product and the B product. (For the B indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard.)

h. The normalized transresistance is -(A product), the normalized transreactance is -(B product).*

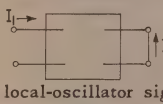
i. To obtain the transimpedance in ohms, multiply the A and B values by 50.

j. Example: if the A indication is 0.21, the B indication 1.03 and the MULTIPLIER setting at +1, the transimpedance is:

$R_{21}$ = -A x M x 50 ohms = -(0.21)(1)(50 ohms) = -10.5 ohms

$X_{21}$ = -B x M x 50 ohms = -(1.03)(1)(50 ohms) = -j51.5 ohms

3.1.8.3 Transfer-Current Ratio (-$\alpha$, $\beta$, $h_f$, $I_2/I_1$).




a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out local-oscillator signal by reversing generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary.

b. Connect Type 874-WO5 Open-Circuit Termination to OUTPUT connector, set MULTIPLIER to ∞, A arm to 1.5, B arm to 0, and adjust OUTPUT LINE for minimum detector deflection (quarter-wavelength condition).

c. Connect Type 874-U U-Block between INPUT and OUTPUT connectors. Adjust INPUT LINE for minimum detector deflection (quarter-wavelength condition; should appear at about the same setting as for OUTPUT LINE).

* Note sign conventions in accompanying diagrams.

d. Connect Type 874-WN5 Short-Circuit Termination to OUTPUT, and set OUTPUT LINE for nearest minimum detector deflection (half-wavelength condition).

e. Connect the input of the network under test to INPUT connector, output to OUTPUT connector, using suitable mount.

f. Apply biases if needed: input to INPUT BIAS, output to OUTPUT BIAS.

g. Adjust arms for null. Try first for null with MULTIPLIER at 1, increasing to a higher value if necessary.

h. Multiply the A and B arm indications by the MULTIPLIER setting to obtain the A product and B product. (For the B indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard.)

i. If the OUTPUT LINE is shorter than the INPUT LINE, the real component is +(B product), the imaginary component -(A product).*

j. If the OUTPUT LINE is longer than the INPUT LINE, the real component is -(B product), the imaginary component +(A product).*

k. Example: if the A indication is 1.15, the B indication -1.4, the MULTIPLIER setting -1, the INPUT LINE and OUTPUT LINE scale settings 161 and 191 respectively, the transfer current ratio is:

$(I_2/I_1)$ real component = -B x M = -(-1.4)(-1) = -1.4

$(I_2/I_1)$ imaginary component = +A x M = +(1.15)(-1) = -j1.15

Accuracy Check.

For an independent, absolute accuracy check on the above measurement, balance the bridge with the Type 874-U U-Block connected to the INPUT and OUTPUT connectors. The result should be -1 +j0. The measured real part of the unknown transfer current ratio (indicated on the B scale) can be corrected for several types of errors if it is divided by the real part of the ratio measured with the U Block.

Correction Procedure.

Another correction technique is to adjust the susceptance standard until the B reading of the U-Block is unity. The imaginary part of the current ratio can be corrected by subtraction of the U-Block A-scale indication from the unknown A reading.

3.1.8.4 Transfer Voltage Ratio ($h_r$) $E_2/E_1$.

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out local-oscillator signal by reversing generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary.

b. Connect Type 874-WN5 Short-Circuit Termination to OUTPUT connector, set MULTIPLIER to $\infty$, A arm to 1.5, B arm to 0, and adjust OUTPUT LINE for minimum detector deflection (half-wavelength condition).

c. Connect Type 874-U U-Block between INPUT and OUTPUT connectors. Adjust INPUT LINE for minimum detector deflection (half-wavelength condition; should appear at about the same setting as for OUTPUT LINE).

d. Connect Type 874-WO5 Open-Circuit Termination to OUTPUT, set OUTPUT LINE for nearest minimum detector deflection (quarter-wavelength condition).

e. Connect the input of the network under test to INPUT, output to OUTPUT, using suitable mount.

f. Apply biases if needed, input to INPUT BIAS output to OUTPUT BIAS.

g. Adjust arms for null. Try first for a null with MULTIPLIER at 1, increasing to a higher value if necessary.

h. Multiply the A and B arm indications by the MULTIPLIER setting to obtain the A product and B product. (For the B indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard.)

i. If the OUTPUT LINE is longer than the INPUT LINE, the real component is -(B product), the imaginary component is +(A product).*

j. If the OUTPUT LINE is shorter than the INPUT LINE, the real component is +(B product), the imaginary component is -(A product).*

k. Example: if the A indication is 1.3, the B indication +0.5, the MULTIPLIER setting +1, and INPUT LINE and OUTPUT LINE scale settings 156 and 180 respectively, the transfer voltage ratio is:

$E_2/E_1$ real component = -B x M = -(0.5)(+1) = -0.5

$E_2/E_1$ imaginary component = +A x M = +(1.3)(+1) = +j1.3

For an independent, absolute accuracy check on the above type of measurement, balance the bridge with the Type 874-U U-Block connected to the INPUT and OUTPUT connectors. The result should be 1 + j0. The measured real part of the unknown transfer voltage ratio (indicated on the B scale) can be corrected for several types of errors if it is divided by the real part of the ratio measured with the U-Block.

Another correction technique is to adjust the susceptance standard until the B reading of the U-Block is unity. The imaginary part of the voltage ratio can be corrected by subtraction of the U-Block A-scale indication from the unknown A reading.

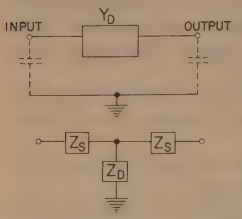
3.1.8.5 Reverse Transfer-Function Measurements. The procedures for reverse transadmittance, reverse transimpedance, reverse transfer current ratio and reverse transfer voltage ratio measurements are the same as those given above for the forward measurements except that network input and output and bias connections should be reversed.

3.1.9 USE OF MULTIPLIER PLATE. To increase the range or resolution of the scales in the measurement of very high or very low values of transfer functions, use the Type 1607-P10 or -P11 Multiplier Plate (refer to paragraph 2.6).

* Note sign conventions in accompanying diagrams.

## 3.2 IMMITTANCE MEASUREMENTS.

### 3.2.1 DIRECT ADMITTANCE OR IMPEDANCE.




Direct, two-terminal impedance and admittance measurements of components can be made with the Transfer-Function Indicator in place. The transadmittance of a device connected between the center conductors of the INPUT and OUTPUT connectors is the direct, two-terminal admittance of that device independent of any stray capacitance to ground. Therefore, the measurement procedure is the same as for transadmittance (paragraph 3.1.8.1), except that if biases are to be connected between the ungrounded terminals, use the red INPUT BIAS and OUTPUT BIAS binding posts. Because of the sign conventions shown in Figure 15A, $Y_D = -Y_{21}$. A transimpedance measurement will determine $Z_D$ shown in the above diagram. $Z_D$ is not the reciprocal of $Y_D$.

The Type 1607-P601 Ungrounded Component Mount will accommodate many types of components for direct, ungrounded measurements.

### 3.2.2 INPUT OR OUTPUT ADMITTANCE ($Y_{11}$ OR $Y_{22}$).

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*

To measure the input admittance of a network with its output short-circuited ($Y_{11}$), or the output admittance with the input short-circuited ($Y_{22}$), make sure the Immittance Indicator is in place and proceed as follows:

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out the local-oscillator signal by reversing the generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary. Set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to $\infty$

b. For maximum accuracy, the standing-wave patterns on the INPUT and OUTPUT LINES during setup should be similar to those during measurement. The standing-wave pattern on the OUTPUT LINE during measurement depends upon what is being measured: for high admittances (over 20 mmhos), a voltage minimum will occur near the unknown end; for low admittances (under 20 mmhos), a voltage maximum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high- and low-admittance measurements. For very low admittances (under 2 mmhos), refer to paragraph 3.2.10.

(1) High admittances (> 20 mmhos).

(a) Connect the Type 874-WN5 Short-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (half-wavelength condition with voltage minimum at unknown end).

(b) Connect the Type 874-U U-Block between INPUT and OUTPUT and adjust the INPUT LINE for minimum detector deflection (half-wavelength condition; should appear at about same setting as for OUTPUT LINE).

(2) Low admittances (< 20 mmhos) (e.g. transistor collector admittance, vacuum-tube plate or grid admittance). (Refer to paragraph 3.2.10 for admittances under 2 mmhos.)

(a) Same as (a) above.

(b) Same as (b) above.

(c) Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and trim the setting of the OUTPUT LINE as follows: Set the MULTIPLIER arm to 1, the REAL and IMAGINARY arms to 0. Adjust the OUTPUT LINE and the REAL arm for a detector null (half-wavelength condition with voltage maximum at unknown end).

c. Plug the network into the NETWORK UNDER TEST terminals. For measurements with the Immittance Indicator, the functions of the INPUT and OUTPUT terminals are interchanged; therefore, to measure input admittance ($Y_{11}$), connect the network input to the OUTPUT connector, and the network output to the INPUT connector. To measure output admittance ($Y_{22}$), reverse these connections. If the network is active, be sure its power supplies are turned off before plugging it into the bridge.

d. To measure input admittance ($Y_{11}$), connect the input bias supply to the OUTPUT BIAS binding posts and the output bias supply to the INPUT BIAS binding posts. To measure output admittance ($Y_{22}$), reverse these connections.

e. If the network is active, turn on the power supplies needed. A transistor's collector supply should normally be turned on first, and the emitter supply then advanced from zero to the operating current. A vacuum tube's grid bias should normally be turned on before high voltages are applied.

f. Adjust arms for a null. Try first for a null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. The normalized conductance and susceptance are the products of the MULTIPLIER setting and the settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 20 mmhos to obtain the admittance components.

h. Example: if the REAL setting is +0.7, the IMAGINARY setting 0.2, and the MULTIPLIER setting +1, the admittance components are:

conductance = +0.7 (+1) (20) = +14 mmhos

susceptance = 0.2 (+1) (20) = +j4 mmhos

3.2.3 INPUT OR OUTPUT IMPEDANCE ($Z_{11}$ or $Z_{22}$).

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*

To measure the input impedance of a network with its output open-circuited ($Z_{11}$), or the output impedance with the input open-circuited ($Z_{22}$), make sure that the Immittance Indicator is in place and proceed as follows:

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out the local-oscillator signal by reversing the generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary. Set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to $\infty$.

b. For maximum accuracy, the standing-wave patterns on the INPUT and OUTPUT LINES during setup should be similar to those during measurement. The standing-wave pattern on the OUTPUT LINE during measurement depends upon what is being measured: for high impedances (over 50 ohms), a voltage maximum will occur near the unknown end; for low impedances (under 50 ohms), a voltage minimum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high- and low-impedance measurements. For very low impedances (under 5 ohms), refer to paragraph 3.2.10.

(1) High impedances (> 50 ohms).

(a) Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (quarter-wavelength condition with voltage maximum at unknown end).

(b) Connect the Type 874-U U-Block between INPUT and OUTPUT and adjust the INPUT LINE for minimum detector deflection (quarter-wavelength condition; should appear at about same setting as for OUTPUT LINE).

(2) Low impedances (< 50 ohms).

(a) Same as (a) above.

(b) Same as (b) above.

(c) Connect the Type 874-WN5 Short-Circuit Termination to the OUTPUT connector and trim the setting of the OUTPUT LINE as follows: Set the MULTIPLIER arm to 1, the REAL and IMAGINARY arms to 0. Adjust the OUTPUT LINE and the REAL arm for a detector null (quarter-wavelength condition with voltage minimum at unknown end).

c. Plug the network into the NETWORK UNDER TEST terminals. For measurements with the Immittance Indicator, the functions of the INPUT and OUTPUT terminals are interchanged; therefore, to measure input impedance ($Z_{11}$), connect the network input to the OUTPUT connector, and the network output to the INPUT connector. To measure output impedance ($Z_{22}$), reverse these connections. If the network is active, be sure its power supplies are turned off before plugging it into the bridge.

d To measure input impedance ($Z_{11}$), connect the input bias supply to the OUTPUT BIAS binding posts, and the output bias supply to the INPUT BIAS binding posts. To measure output impedance ($Z_{22}$), reverse these connections.

e. If the network is active, turn on the power supplies needed. A transistor's collector supply should normally be turned on first, and the emitter supply then advanced from zero to the operating current. A vacuum tube's grid bias should normally be turned on before high voltages are applied.

f. Adjust arms for a null. Try first for a null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. The normalized resistance and reactance are the products of the MULTIPLIER setting and the settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 50 to obtain the impedance components in ohms.

h. Example: if the REAL setting is +0.7, the IMAGINARY setting +0.9, and the MULTIPLIER setting 2, the impedance components are:

resistance = REAL x M x 50 ohms =
+0.7 (2) (50) = 70 ohms

reactance = IMAGINARY x M x 50 ohms =
+0.9 (2) (50) = +j90 ohms

3.2.4 HYBRID OUTPUT ($h_o$) OR INPUT ADMITTANCE.

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*

To measure the input admittance of a network with its output open-circuited or output admittance with the input open-circuited ($h_o$), make sure that the Immittance Indicator is in place and proceed as follows:

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out the local-oscillator signal by reversing generator and local-oscillator connections and adjusting trap for null. Then restore normal connections. Connect low-frequency extensions if necessary. Set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to $\infty$.

b. For maximum accuracy, the standing-wave patterns on the INPUT and OUTPUT LINES during setup should be similar to those during measurement. The standing-wave pattern on the OUTPUT LINE during measurement depends upon what is being measured: for high hybrid admittances (over 20 mmhos), a voltage minimum will occur near the unknown end; for low hybrid admittances (under 20 mmhos), a voltage maximum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high and low hybrid admittance measurements. For very low hybrid admittances (under 2 mmhos), refer to paragraph 3.2.10.

(1) High hybrid admittances (> 20 mmhos).

(a) Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (quarter-wavelength condition).

(b) Connect the Type 874-U U-Block between INPUT and OUTPUT and adjust the INPUT LINE for minimum detector deflection (quarter-wavelength condition; should appear at about the same setting as for OUTPUT LINE).

(c) Connect the Type 874-WN5 Short-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (half-wavelength condition with voltage minimum at unknown end).

(2) Low hybrid admittances (< 20 mmhos).

(a) Same as (a) above.

(b) Same as (b) above.

(c) Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and adjust setting of the OUTPUT LINE as follows: Set the MULTIPLIER arm to 1, the REAL and IMAGINARY arms to 0. Adjust the OUTPUT LINE and the REAL arm for a detector null (half-wavelength condition with voltage maximum at unknown end).

c. Plug the network into the NETWORK UNDER TEST terminals. For measurements with the Immittance Indicator, the functions of the INPUT and OUTPUT terminals are interchanged; therefore, to measure hybrid input admittance, connect the network input to the OUTPUT connector and the network output to the INPUT connector. To measure hybrid output admittance ($h_o$), reverse these connections. If the network is active, be sure its power supplies are turned off before plugging it into the bridge.

d. To measure hybrid input admittance, connect the input bias supply to the OUTPUT BIAS binding posts and the output bias supply to the INPUT BIAS binding posts. To measure hybrid output admittance ($h_o$), reverse these connections.

e. If the network is active, turn on the power supplies needed. A transistor's collector supply should normally be turned on first, and the emitter supply then advanced from zero to the operating current. A vacuum tube's grid bias should normally be turned on before high voltages are applied.

f. Adjust arms for a null. Try first for a null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. The normalized conductance and susceptance are the products of the MULTIPLIER setting and the settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 20 to obtain the hybrid admittance components in mmhos.

h. Example: if the REAL setting is +0.05, the IMAGINARY setting +0.6, and the MULTIPLIER setting +1, the hybrid admittance components are:

$$\text{conductance} = \text{REAL} \times M \times 20 \text{ mmhos} = +0.05\ (1)\ (20) = 1 \text{ mmho}$$

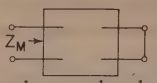
$$\text{susceptance} = \text{IMAGINARY} \times M \times 20 \text{ mmhos} = +0.6\ (1)\ (20) = +j12 \text{ mmhos}$$

NOTE

In some active networks oscillations occur in this measurement. A damper unit (refer to paragraph 6.5) cannot be used in this instance, so if oscillations do occur (usually indicated by an inability to obtain a complete null), it may be necessary to determine $h_o$ from other measurements. For instance: $h_o = Y_{22} + \frac{h_r h_f}{h_i}$

3.2.5 HYBRID INPUT ($h_i$) OR OUTPUT IMPEDANCE.

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*




To measure the input impedance of a network with its output short-circuited ($h_i$) or the output impedance with the input short-circuited, make sure that the Immittance Indicator is in place and proceed as follows:

a. Set generator, local oscillator, and susceptance standard to desired frequencies. If network is nonlinear or active, trap out the local-oscillator signal by reversing the generator and local-oscillator connections and adjusting the trap for a null. Then restore normal connections. Connect low-frequency extensions if necessary. Set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to ∞.

b. For maximum accuracy, the standing-wave patterns on the INPUT and OUTPUT LINES during setup should be similar to those during measurement. The standing-wave pattern on the OUTPUT LINE during measurement depends upon what is being measured: for high hybrid impedances (over 50 ohms), a voltage maximum will occur near the unknown end; for low hybrid impedances (under 50 ohms), a voltage minimum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high and low hybrid impedance measurements. For very low hybrid impedances (under 5 ohms), refer to paragraph 3.2.10.

(1) High hybrid impedances (> 50 ohms).

(a) Connect the Type 874-WN5 Short-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (half-wavelength condition).

(b) Connect the Type 874-U U-Block between INPUT and OUTPUT and adjust the INPUT LINE for minimum detector deflection (half-wavelength condition; should appear at about same setting as for OUTPUT LINE).

(c) Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection (quarter-wavelength condition with voltage maximum at unknown end).

(2) Low hybrid impedances (< 50 ohms).

(a) Same as (a) above.

(b) Same as (b) above.

(c) Connect the Type 874-WN5 Short-Circuit Termination to the OUTPUT connector and adjust setting of the OUTPUT LINE as follows: Set the MULTIPLIER arm to 1, the REAL and IMAGINARY arms to 0. Adjust the OUTPUT LINE and the REAL arm for a detector null (quarter-wavelength condition with voltage minimum at unknown end).

c. Plug the network into the NETWORK UNDER TEST terminals. For measurements with the Immittance Indicator, the functions of the input and output terminals are interchanged; therefore, to measure hybrid input impedance ($h_i$), connect the network input to the OUTPUT connector and the network output to the INPUT connector. To measure hybrid output impedance, reverse these connections. If the network is active, be sure its power supplies are turned off before plugging it into the bridge.

d. To measure hybrid input impedance ($h_i$), connect the input bias supply to the OUTPUT BIAS binding posts and the output bias supply to the INPUT BIAS binding posts. To measure hybrid output impedance, reverse these connections.

e. If the network is active, turn on the power supplies needed. A transistor's collector supply should normally be turned on first, and the emitter supply then advanced from zero to the operating current. A vacuum tube's grid bias should normally be turned on before high voltages are applied.

f. Adjust arms for a null. Try first for a null with MULTIPLIER at 1, increasing to a higher value if necessary.

g. The normalized resistance and reactance are the products of the MULTIPLIER setting and the settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 50 to obtain the hybrid impedance components in ohms.

h. Example: if the REAL setting is 0.5, the IMAGINARY setting -0.2, and the MULTIPLIER setting 10, the hybrid impedance components are:

resistance = REAL x M x 50 ohms =
0.5 (10) (50) = 250 ohms

reactance = IMAGINARY x M x 50 ohms =
-0.2 (10) (50) = -j100 ohms

3.2.6 ADMITTANCE OF GROUNDED TWO-TERMINAL COMPONENTS.

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*

In the following procedure, the use of the Type 874-ML Component Mount dictates the use of a 3-cm termination (Type 874-WN3 Short-Circuit Termination) for setting the OUTPUT LINE. The OUTPUT LINE is set to a multiple of a half wavelength ($\lambda/2$), and the INPUT LINE is not used. One section of the Type 1607-P601 Ungrounded Component Mount can also be used, in which case Type 874-WN5 and -WO5 Terminations replace the -WN3 and -WO3 in the following procedure.

a. With the Immittance Indicator in place, set generator, local oscillator and susceptance standard to desired frequencies. If the unknown is nonlinear or active, trap out the local-oscillator signal by reversing generator and local-oscillator connections and adjusting trap for null. Then restore normal connections. Connect low-frequency extensions if necessary.

b. For maximum accuracy, the standing-wave pattern on the OUTPUT LINE during setup should be similar to that during measurement. The pattern during measurement depends on what is being measured: for high admittances (over 20 mmhos), a voltage minimum will occur near the unknown end; for low admittances (under 20 mmhos), a voltage maximum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high- and low-admittance measurements. For very low admittances (under 2 mmhos), refer to paragraph 3.2.10.

(1) High Admittances (> 20 mmhos).

Connect the Type 874-WN3 Short-Circuit Termination (furnished with the Type 874-ML Mount) to the OUTPUT connector, set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to $\infty$. Adjust the OUTPUT LINE for minimum detector deflection (half-wavelength condition with voltage minimum at unknown end).

(2) Low Admittances (< 20 mmhos).

Connect the Type 874-WO3 Open-Circuit Termination (furnished with the Type 874-ML Mount) to the OUTPUT connector. Set the MULTIPLIER arm to 1 and set the REAL and IMAGINARY arms to 0. Then adjust the OUTPUT LINE and the REAL arm for a detector null (half-wavelength condition with voltage maximum at unknown end).

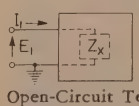
c. With the component being measured connected inside the Type 874-ML Component Mount, plug the mount into the OUTPUT connector. If component is active, be sure its power supplies are turned off before plugging it into the Bridge. Connect bias, if used, to OUTPUT BIAS binding posts.

d. Adjust arms for a null. Try first for a null with MULTIPLIER set at 1, increasing to a higher value if necessary.

e. The normalized conductance and susceptance are the products of the MULTIPLIER setting and settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 20 to obtain the admittance components in mmhos.

3.2.7 IMPEDANCE OF GROUNDED TWO-TERMINAL COMPONENTS.

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*




In the following procedure, the use of the Type 874-ML Component Mount dictates the use of a 3-cm termination (Type 874-WO3 Open-Circuit Termination) for setting the OUTPUT LINE. The INPUT LINE is not used, and the OUTPUT LINE is set to an

odd multiple of a quarter wavelength. One section of the Type 1607-P601 Ungrounded Component Mount can also be used, in which case Type 874-WN5 and -WO5 Terminations replace the -WN3 and -WO3 in the following procedure.

a. With the Immittance Indicator in place, set the generator, local oscillator, and susceptance standard to desired frequencies. If the unknown is nonlinear or active, trap out the local-oscillator signal by reversing generator and local-oscillator connections and adjusting trap for null. Then restore normal connections. Connect low-frequency extensions if necessary.

b. For maximum accuracy, the standing-wave pattern on the OUTPUT LINE during setup should be similar to that during measurement. The pattern during measurement depends on what is being measured: for high impedances (over 50 ohms), a voltage maximum will occur near the unknown end; for low impedances (under 50 ohms), a voltage minimum will occur near the unknown end. Thus, for maximum accuracy, alternate setup procedures are given for high- and low-impedance measurements. For very low impedances (under 5 ohms), refer to paragraph 3.2.10.

(1) High impedances (> 50 ohms).

Connect the Type 874-WO3 Open-Circuit Termination (furnished with the Type 874-ML Mount) to the OUTPUT connector, set REAL arm to 1.0, IMAGINARY arm to 0, and MULTIPLIER arm to ∞. Adjust the OUTPUT LINE for minimum detector deflection (quarter-wavelength condition with voltage maximum at unknown end).

(2) Low impedances (< 50 ohms).

Connect the Type 874-WN3 Short-Circuit Termination (furnished with the Type 874-ML Mount) to the OUTPUT connector. Set the MULTIPLIER arm to 1 and set the REAL and IMAGINARY arms to 0. Then adjust the OUTPUT LINE and REAL arm for detector null (quarter-wavelength condition with voltage minimum at unknown end).

c. With the component being measured connected inside the Type 874-ML Component Mount, plug the mount into the OUTPUT connector. If the component is active, be sure its power supplies are turned off before plugging it into the bridge. Connect BIAS, if used, to OUTPUT BIAS binding posts.

d. Adjust arms for a null. Try first for a null with MULTIPLIER set at 1, increasing to a higher value if necessary.

e. The normalized resistance and reactance are the products of the MULTIPLIER setting and the settings of the REAL and IMAGINARY scales, respectively. For the IMAGINARY indication, use the sign whose color is the same as that of the frequency scale used on the susceptance standard. Multiply the normalized values by 50 to obtain the impedance components in ohms.

3.2.8 DIRECT MEASUREMENT OF IMPEDANCE OR ADMITTANCE MAGNITUDE.

*NOTE: For a fuller discussion of line-adjustment procedure, refer to Section 3.1.2.*

To measure the magnitude of an unknown impedance directly, make sure the Immittance Indicator is in place and proceed as follows:

a. Set the generator to the desired frequency of measurement and set the local oscillator so that the difference frequency equals the intermediate frequency. Connect the low-frequency Range Extension Unit if needed. Plug the Type 1607-P4 Termination into the conductance standard connector at the left of the junction block. The susceptance standard is not required, but if it is not connected, insert a Type 874-WO3 Open-Circuit Termination in the susceptance standard connector to prevent radiation. If the stub is used, set it near the operating frequency.

b. Set the IMAGINARY indicator to zero, the REAL indicator to 1.0, and the MULTIPLIER to ∞.

c. Connect the Type 874-WO5 Open-Circuit Termination to the OUTPUT connector and adjust the OUTPUT LINE for minimum detector deflection ($\lambda/4$ line length).

d. Connect the unknown to the OUTPUT connector.

e. Record the output voltage indicated on the detector with the detector operating linearly (no AVC), and call it $V_1$.

f. Reset the REAL indicator to zero and the MULTIPLIER to 1, and again record the output voltage ($V_2$).

g. Calculate the magnitude of the unknown impedance (seen at a point along the unknown line directly under the loop coupling) as follows:

$$\frac{|Z_x|}{|Z_o|} = \frac{|V_2|}{|V_1|}, \text{ or } |Z_x| = 50\left(\frac{|V_2|}{|V_1|}\right) \text{ ohms.} \qquad (1)$$

h. The procedure for direct measurement of the magnitude of an unknown admittance is the same as above except that the OUTPUT LINE should be set to a half wavelength (i.e., use a Type 874-WN5 instead of -WO5 in step c). The formula of step g becomes:

$$\frac{|Y_x|}{|Y_o|} = \frac{|V_1|}{|V_2|}, \text{ or } |Y_x| = 20\left(\frac{|V_1|}{|V_2|}\right) \text{ millimhos.} \qquad (2)$$

3.2.9 MEASUREMENT OF LOSS COMPONENT OF HIGH-Q ELEMENTS.

3.2.9.1 General. The resistance or conductance of many high-Q elements can be measured more accurately without resort to any correction equations by the following procedure: a short- or open-circuited length of air line is connected, as described below, to the OUTPUT connector, and the OUTPUT LINE is adjusted so that its reactance or susceptance is approximately equal to that of the unknown. For a first approximation, the conductance or resistance of the air line can be assumed to be zero; therefore, any measured value different from zero is an error within the instrument. This error should be algebraically subtracted from the conductance or resistance measured with the unknown connected. (If the adjustment range of the OUTPUT LINE is insufficient, additional lengths of Type 1607-P7 Air Line can be added.) For greatest accuracy in the real component, use a quarter-wave line and measure impedance if the unknown impedance is high compared to $Z_o$, and use a half-wave line and measure admittance if the impedance is low compared to $Z_o$.

a. The procedure for the quarter-wave case is as follows:

(1) Set the OUTPUT LINE to $\lambda/4$ in the usual manner and determine the settings of the REAL, IMAGINARY, and MULTIPLIER arms, $A_o$, $B_o$, and M with the unknown connected.

(2) If the product of the MULTIPLIER and IMAGINARY readings is larger than unity, substitute a Type 874-WO5 Open-Circuit Termination for the unknown, and shorten or lengthen[1] the OUTPUT LINE and adjust the REAL arm until a balance is produced. Do not change the IMAGINARY or MULTIPLIER arm settings. If the range of adjustment is insufficient, add lengths of Type 1607-P7 Air Line until a balance is obtained. If more than a quarter-wave section of line must be added, or if it appears that the balance could be obtained if the line were shortened not far beyond its range, more accurate results can be obtained if a Type 874-WN5 Short-Circuit Termination, rather than an open-circuit termination, is substituted for the unknown and the instrument balanced as above with the addition of sections of air line if necessary. In either case, record the REAL arm setting, $A_1$.

(3) Determine the effective resistance, $R_x$, and the reactance, $X_x$.

$$R_x = 50M(A_o - A_1) \text{ ohms} \quad (3)$$

$$X_x = 50MB_o \text{ ohms} \quad (4)$$

b. The procedure for the half-wave case is as follows:

(1) Set the OUTPUT LINE to $\lambda/2$ in the usual manner and determine the settings of the REAL, IMAGINARY, and MULTIPLIER arms, $A_o$, $B_o$, and M with the unknown connected.

(2) If the product of the MULTIPLIER and IMAGINARY readings is larger than unity, substitute a Type 874-WN5 Short-Circuit Termination for the unknown and proceed as described in a. (2), except interchange short- and open-circuit terminations.

(3) Determine the effective conductance, $G_x$, and susceptance, $B_x$.

$$G_x = 20M(A_o - A_1) \text{ millimhos} \quad (5)$$

$$B_x = 20MB_o \text{ millimhos} \quad (6)$$

3.2.9.2 Use of Multiplier Plate. Greater accuracy in the real component can be obtained by the use of the Type 1607-P10 Single Multiplier Plate (refer to paragraph 2.6).

3.2.10 MEASUREMENT OF HIGH-IMPEDANCE (LOW-ADMITTANCE) CIRCUITS.

3.2.10.1 General. In the measurement of very high impedance (compared with 50 ohms) circuits, such as the collector impedance of transistors, plate and grid impedances of tubes, etc, the accuracy can be significantly improved if the admittance rather than the impedance of the unknown is measured. The OUTPUT LINE should be set to one-half wavelength as described in step b (2) of paragraph 3.2.2, 3.2.4, or 3.2.6, depending upon the measurement desired. The REAL arm indication obtained when the line length is adjusted should be subtracted from that obtained with the unknown connected. The accuracy can be further increased by the use of a multiplier plate.

3.2.10.2 Multiplier-Plate Method. In this method the Type 1607-P11 Multiplier Plate is installed in place of the gasket (refer to paragraph 2.6). Orient the plate so that the two small coupling holes cover the slots associated with the conductance and susceptance standards. With the multiplier plate installed, the MULTIPLIER indication must be multiplied by 0.1; thus smaller magnitudes of conductance and susceptance can be resolved on the dials. To apply a multiplier to only one component of admittance, use the Type 1607-P10 Multiplier Plate. Place the small hole over the appropriate slots in the head (refer to paragraph 2.6).

3.2.10.3 Direct Measurement of High Impedance. If very high impedance (very low admittance) is to be measured and if for any reason it is desired to measure impedance instead of admittance as recommended in paragraph 3.2.10.1, the Type 1607-P10 Multiplier Plate can be used to extend the upper impedance limit by a factor of 10 (refer to paragraph 2.6). Place the small coupling hole in the multiplier plate over the $M_I$ slots, set the OUTPUT LINE as described in step b (1) of paragraph 3.2.3, 3.2.5, or 3.2.7, depending upon the measurement desired. In this method accuracy will not be so good as in the methods described in paragraphs 3.2.10.1 and 3.2.10.2.

3.2.11 MEASUREMENT OF LOW-IMPEDANCE (HIGH-ADMITTANCE) CIRCUITS.

3.2.11.1 General. For measurements of very low-impedance (compared with 50 ohms) circuits, the accuracy can be significantly improved if the impedance rather than the admittance of the unknown is measured. Set the OUTPUT LINE to one-quarter wavelength as described in step b (2) of paragraph 3.2.3, 3.2.5, or 3.2.7, depending upon the measurement desired. The REAL arm indication obtained when the line length is adjusted should be subtracted from that obtained with the unknown connected. The accuracy can be further increased by use of a multiplier plate.

3.2.11.2 Multiplier-Plate Method. In this method the Type 1607-P11 Multiplier Plate is installed in place of the gasket (refer to paragraph 2.6). Orient the plate so that the two small coupling holes cover the slots associated with the resistance and reactance standards. With the multiplier plate installed, the MULTIPLIER indication must be multiplied by 0.1; thus

[1] For most accurate results, instead of adjusting the OUTPUT LINE, substitute for the unknown a short or open-circuited air line of a length that will produce approximately the same imaginary component as the unknown.

smaller magnitudes of resistance and reactance can be resolved on the dials. To apply a multiplier to only one component of impedance use the Type 1607-P10 Multiplier Plate. Place the small coupling hole over the appropriate slots in the head (refer to paragraph 2.6).

3.2.11.3 Direct Measurement of High Admittance. If a very high admittance (very low impedance) is to be measured, and if for any reason it is desired to measure admittance instead of impedance as recommended in paragraph 3.2.11.1, the Type 1607-P10 Multiplier Plate can be used to extend the upper admittance limit by a factor of 10 (refer to paragraph 2.6). Place the small coupling hole over the $M_1$ slots. Set the OUTPUT LINE as described in step b (1) of paragraph 3.2.2, 3.2.4, or 3.2.6, depending upon the measurement desired. In this method the accuracy will not be so good as in the methods described in paragraphs 3.2.11.1 and 3.2.11.2.

3.3 REFLECTION COEFFICIENT AND VSWR. Reflection coefficient ($\Gamma$) and standing-wave ratio on a 50-ohm line can be calculated from the complex components of impedance as follows:

$$|\Gamma| = \left|\frac{Y_o - Y_x}{Y_o + Y_x}\right| = \sqrt{\frac{(G_o - G_x)^2 + (B_x)^2}{(G_o + G_x)^2 + (B_x)^2}} \qquad (9)$$

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \qquad (10)$$

or can be obtained by use of a Smith Chart or measured by the following ratio method:

a. With the Immittance Indicator in place, connect the Type 1607-P4 Termination in place of the susceptance standard and leave the conductance standard connector open-circuited. Set the REAL arm to zero and the MULTIPLIER to 1. Set the generator and local oscillator to desired frequencies, and connect low-frequency extensions if necessary.

b. Connect the line under test to the OUTPUT connector (the line lengths do not affect this measurement).

c. Apply bias if necessary to the OUTPUT BIAS connector.

d. Set the IMAGINARY arm to +1.0, and record the output indicated by the detector.

e. Shift the IMAGINARY arm to -1.0 and again record the output.

f. If the outputs are given in decibels (as on the Type 1216-A Unit I-F Amplifier), the equivalent voltage ratio (magnitude of reflection coefficient) can be computed from the equation

$$|\Gamma| = \frac{V_1}{V_2} = \text{antilog}\left(\frac{A_1 - A_2}{20}\right) \qquad (11)$$

where $A_1$ and $A_2$ are the decibel indications, and $\Gamma$ equals reflection coefficient, or the correlation may be determined from the decibel tables given at the back of this manual. The db difference ($A_1 - A_2$) should be a negative number, since the voltage ratio and reflection coefficient are numbers less than unity.

g. Voltage-standing-wave ratio can then be calculated readily from equation (10) or determined from Appendix 1 in the back of this manual.

3.4 IMPEDANCE MATCHING TO A 50-OHM LINE. The Immittance Bridge can be used to match a load to a 50-ohm line as follows:

a. Connect the generator and detector to desired frequencies of measurement, connect the Type 1607-P4 Termination in the conductance-standard connector at the left of the tuning block. The susceptance standard need not be used. If it is not used, plug a Type 874-WO3 Open-Circuit Termination into the susceptance standard connector. If the standard stub is used, set it near the operating frequency.

b. Connect the line under test to the OUTPUT connector.

c. Set the REAL indicator to 1.0, the IMAGINARY indicator to 0, and the MULTIPLIER to 1.

d. The nearness of the impedance match is indicated by the magnitude of the output voltage; zero output means a perfect match. The detector output gives a continuous indication of nearness of match.

e. The resultant output voltage, V, is proportional to the reflection coefficient for small values of reflection coefficient ($\Gamma$). The actual relationship is

$$|V| = k\left|\frac{\Gamma}{1 - \Gamma}\right| \qquad (12)$$

3.5 MEASUREMENTS ON 75-OHM LINES.

3.5.1 IMPEDANCE AND ADMITTANCE. Measurements on 75-ohm lines consist of connecting the 75-ohm line to a 50-ohm line, which in turn is connected to the Type 1607-A, and then determining the impedance or admittance at the junction of the 50-ohm and 75-ohm lines. One method of connecting these lines to each other is by means of a Type 874 connector attached to the 75-ohm cable. Refer to Appendix 3 for proper connectors for various types of lines. The junction between the 50- and 75-ohm lines is made at the point indicated in Figure 12, where the electrical length, $\ell$, is 2.6 cm (physical length: 2.4 cm). There is a slight discontinuity at the junction caused by stray reactances, but the effect is negligible in most applications.

To make the measurement, first attach a Type 874-WO3 or -WN3 Termination to the OUTPUT connector and adjust the OUTPUT LINE to a half wavelength (for admittance measurements), or a quarter wavelength (for impedance measurements). Refer to paragraph 3.1.2 for line-adjustment procedure. After the line is adjusted, it is necessary to add 0.6 cm to the setting to compensate for the different reference planes between the 75- and 50-ohm junction and the Type 874-WO3 or -WN3.

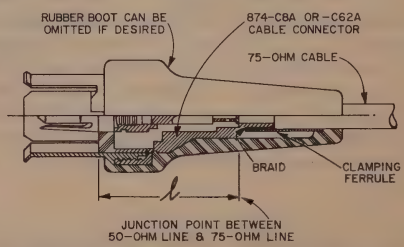



Figure 12. Cross-Section of Type 874-C62 Cable Connector with 75-Ohm Cable Attached.

After the OUTPUT LINE is adjusted, connect the 75-ohm line (with the 50-ohm connector) to the OUTPUT connector and balance the bridge. If impedance is being measured, series resistive and reactive components in ohms are given by the REAL and IMAGINARY indications respectively, multiplied by the MULTIPLIER and by 50. If admittance is being measured, parallel conductance and susceptance components in mmhos are given by the REAL and IMAGINARY indications, respectively, multiplied by the MULTIPLIER and by 20.

3.5.2 REFLECTION COEFFICIENT AND VSWR. The reflection coefficient and VSWR on a 75-ohm line can be calculated from the input impedance or admittance (refer to equation 9), or they can be measured directly by a voltage-ratio method similar to that outlined for 50-ohm lines, paragraph 3.3. However, for measurements on a 75-ohm line, the line must first be fitted to a Type 874 50-ohm connector as described in paragraph 3.5.1. Then the measurement procedure is as follows:

a. Adjust the OUTPUT LINE to a half wavelength as described in paragraph 3.1.2.2. Add 0.6 to the scale indication to compensate for the different reference planes on the Type 874 Cable Connector and the Type 874-WO3 Open-Circuit Termination.

b. Connect the unknown line to the OUTPUT connector and the Type 1607-P4 Termination to the susceptance-standard connector. Leave the conductance-standard connector open-circuited.

c. Set the IMAGINARY arm to +0.666, the REAL arm to 0, and record the output indicated on the detector.

d. Shift the IMAGINARY arm to -0.666 and again record the output.

e. If the outputs are given in decibels (as on the Type 1216-A Unit I-F Amplifier), the equivalent voltage ratio (magnitude of reflection coefficient) can be computed from equation (11) or determined from Appendix 1 at the back of this manual.

3.6 MEASUREMENTS ON LINES WITH IMPEDANCES OTHER THAN 50- OR 75-OHMS. Impedance and admittance measurements on lines whose characteristic impedances are other than 50- or 75-ohms can be made with the Immittance Bridge as described in paragraph 3.5.1. Reflection coefficient and VSWR can be measured as described in paragraph 3.5.2, except that in steps c and d the settings either side of 0 should be $50/Z_o$, where $Z_o$ is the characteristic impedance of the line. For a 72-ohm line, for instance, the IMAGINARY arm settings in steps c and d would be +0.695 and -0.695, respectively.

3.7 MEASUREMENTS ON BALANCED TRANSMISSION LINES. Measurements on balanced lines can be made with the aid of a Type 874-UBL Balun (see Figure 13) which transforms the balanced immittance into an unbalanced immittance, the two related by a factor of four. The balun is a versatile device that introduces negligible error in the measurements and that can be used over almost the entire frequency range of the Type 1607-A.

The balun uses an artificial half-wave line to effect the balanced-to-unbalanced transformation. This line is made up of two sections of coaxial line and two stub lines or capacitors. The lengths of the coaxial line sections are changed for various frequencies; at low frequencies two Type 874-VCL Variable Capacitors are used in place of the stubs. The balun can be tuned to

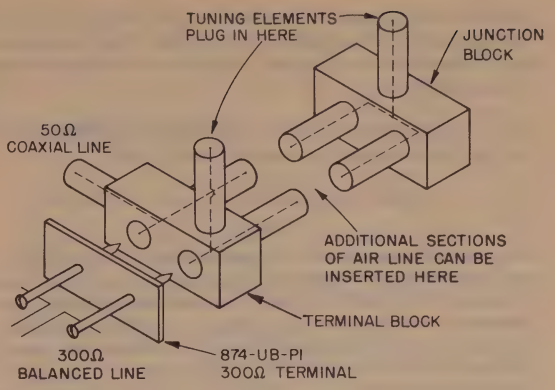



Figure 13. Functional Arrangement of Balun.

the operating frequency very easily by means of the stubs or by the variable capacitors. (Refer to Type 874-UBL Operating Instructions.) While tuning the balun, do not leave the OUTPUT LINE set exactly to a half or quarter wavelength.

After the balun is tuned to frequency, its coaxial output terminal should be connected to the OUTPUT connector of the bridge. In setting the Immittance Bridge OUTPUT line, use the Types 874-WO3 and 874-WN3 Open and Short Circuits. Then measurements can be made as described previously. Because of the four-to-one impedance transformation inherent in the balun, admittance results must be divided by 4, and impedance results multiplied by 4 when the balun is used with the Type 1607-A.

Several different types of terminals are available for use with the balun; refer to balun instruction book or catalog description.

3.8 OPERATION AT FREQUENCIES ABOVE 1000 MC. No direct calibrations are provided on the Type 1607-P1 Susceptance Standard for operation between 1000 and 1500 Mc. To set the stub for frequencies between 1000 and 1500 Mc, divide the signal frequency by five and set the stub to the quotient frequency, using the white scale. The stub should then be checked and adjusted in accordance with paragraph 3.1.3. For some applications the instrument is useful up to 2000 Mc.

3.9 ERRORS AND CORRECTIONS.

3.9.1 GENERAL. The major sources of error are incidental losses and small reflections in the INPUT and OUTPUT LINES. Minor sources of error are spurious cross couplings between the coupling loops and associated lines, inductances between the junction center and the coupling points, incidental losses in the susceptance standard and small reflections in the conductance standard.

3.9.2 LINE-LOSS CORRECTIONS. A correction for line loss is generally not required except for extremely high or low immittance or transfer measurements. Also, the loss correction for any measurement except small values of admittance (1 mmho or less) is usually complex. For reasonable accuracy, this requires special measurement of the line loss for the particular line com-

bination being employed. Therefore, only the correction for the measurement of low admittance is furnished. For measurement of low admittance, the correction procedure for line loss is given in paragraph 3.2.10.1.

3.9.3 LOSS CHARACTERISTICS OF COAXIAL ELEMENTS. The loss characteristic of a coaxial line is given by

$$\text{Loss} = e^{\left(\frac{d\ell}{8.69}\right)} \qquad (17)$$

where $\ell$ is the length, and d is the attenuation in decibles per unit length. Figure 14 gives the attenuation of the three types of coaxial lines used with the Transfer-Function Bridge. To determine total loss for each (input or output) line, multiply the losses of the individual sections. To determine the physical lengths of the Type 1607-P8 Solid-Dielectric Lines, multiply their marked electrical lengths in cm by 0.65. Figure 14 is based on physical length.

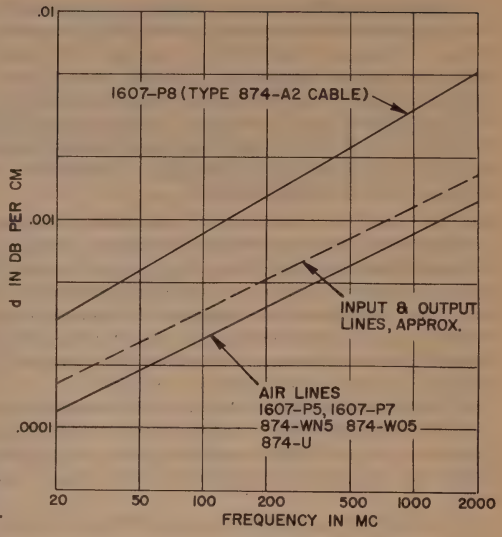



Figure 14. Attenuation of Three Types of Coaxial Line.

# Section 4
# PRINCIPLES OF OPERATION

4.1 GENERAL. The performance of most electrical devices and circuits can be described in terms of so-called "transfer functions" and input and output functions. A transfer function is the ratio of an output to an input quantity, or vice versa, and examples of transfer functions are the alpha and beta current ratios of transistors, the transconductance of vacuum tubes, the gain of amplifiers, and the loss of attenuators and filters.

A common way of specifying characteristics of a four-terminal network such as that shown in Figure 15 is to specify four short-circuit admittances or four open-circuit impedances. Some of these are two-terminal input or output quantities, and some are four-terminal transfer quantities relating conditions between the two sets of terminals. The short-circuit admittances are:

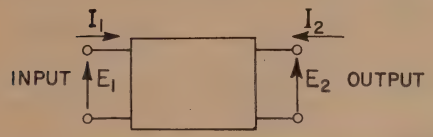
$Y_{11} = I_1/E_1$ with output short-circuited

$Y_{22} = I_2/E_2$ with input short-circuited (network driven from output side)

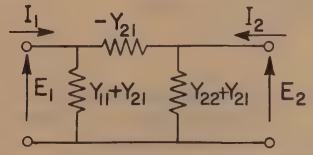
$Y_{21} = I_2/E_1$ with output short-circuited

$Y_{12} = I_1/E_2$ with input short-circuited (network driven from output side)

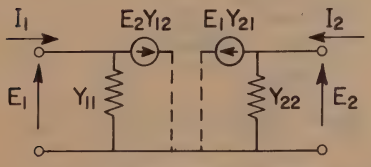
$Y_{11}$ and $Y_{22}$ are two-terminal admittances, $Y_{21}$ is a forward transfer admittance or "forward transadmittance", and $Y_{12}$ is a reverse transfer admittance, often called "feedback admittance". Note sign conventions of currents and voltages in Figure 15!



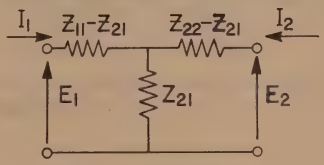

A. General network configuration, showing sign conventions.



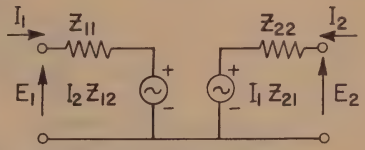

B. Pi-Section equivalent of passive four-terminal network.



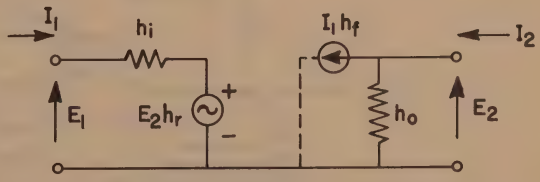

E. Short-circuit admittance parameter representation of active four-terminal networks. Generators indicated are current generators.




C. T-section equivalent of passive four-terminal network.




D. Open-circuit-impedance parameter representation of active four-terminal networks. Generators indicated are zero-impedance voltage generators.




F. Equivalent network representations of transistors. (Voltage source has zero impedance, and output circuit is fed by constant-current generator $I_1 h_f$.

Figure 15. Equivalent Circuits for Transfer-Function and Immittance Bridge.

At low frequencies, $Y_{21}$ is a pure real number, called transconductance, which is generally published in tube handbooks. At uhf and vhf, however, the transadmittance $Y_{21}$ is a complex number, and relatively little is known about its behavior for tubes and transistors.

The Type 1607-A Transfer-Function and Immittance Bridge measures forward or reverse transadmittance by a null method, yielding direct answers in millimhos of transconductance and millimhos of transsusceptance, over a frequency range of from 25 to about 1500 Mc. The instrument also measures transimpedance, complex voltage transfer ratio, complex current transfer ratio and several other quantities discussed in following paragraphs.

4.2 CIRCUIT DESCRIPTION. The bridge is shown schematically in Figure 16. Three identical loops, one associated with the "B" line, one with the "G" line, and one with the "Network Input" line, are driven in parallel by an external generator adjusted to the desired frequency of measurement. The currents ($I_L$) in all three loops are equal in magnitude and phase. Each loop is loosely inductively coupled, through electrostatically shielding slots, to an associated coaxial line. (In Figure 16, only the inner conductors are shown.) Each loop can be rotated independently of the others to vary its coupling, or mutual inductance, to its associated line. The mutual inductances are designated $M_G$, $M_B$, and $M_X$. The series voltages induced in the three lines by virtue of the couplings to the associated loops are: $E_G = -j\omega M_G I_L$, $E_B = -j\omega M_B I_L$, and $E_X = -j\omega M_X I_L$.

The outer end of the "G" line terminates in a known standard conductance, $Y_o$ (20 millimhos). The characteristic admittance of the coaxial lines and connectors used in the instrument is also 20 millimhos (characteristic impedance, $Z_o$, is 50 ohms). The outer end of the "B" line terminates in a known standard susceptance of $+jY_o$ at frequencies below 150 Mc (adjustable capacitor), $-jY_o$ from 150 to 450 Mc (adjustable stub set to $\lambda/8$), and $+jY_o$ above 450 Mc (stub set to $3\lambda/8$). The far end of the third line, the adjustable "Network Input" line, is connected to the input of the network under test, and its electrical length is always set to either an odd or an even multiple of a quarter wavelength, depending on the type transfer function being measured.

The left-hand end of the "Network Input" line terminates in a short circuit. The inner ends of the B and G lines come together at a junction with two other lines. One of these lines is connected to an external detector. The other, the adjustable "Network Output" line, is connected to the output of the network under test. Its electrical length is always set to either an odd or an even multiple of a quarter wavelength, depending on the type transfer function being measured, but not necessarily the same multiple as that to which the "Network Input" line is set.

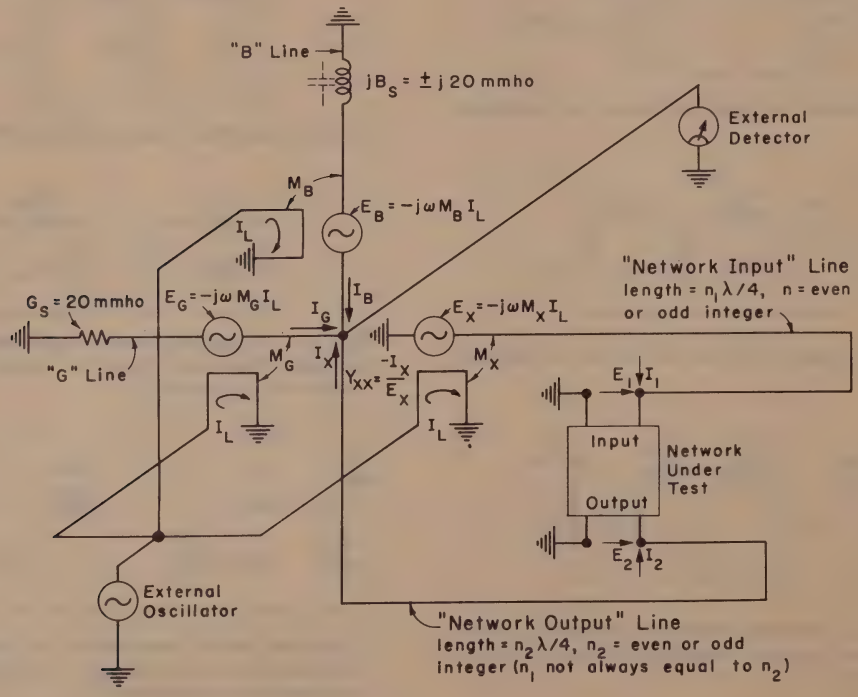



Figure 16a. Schematic Diagram for Transfer-Function Measurements.

4.3 BALANCING PROCEDURE. The process of measuring complex quantities involves the balancing of the instrument by adjustment of the loop couplings until the external detector shows a null. At null, the voltage at the junction of the four coaxial lines is zero, and the three currents ($I_G$, $I_B$, and $I_X$) that enter the detector junction from the "G", "B", and "Network Output" lines, respectively, must add up to zero. These currents are easily calculated, because the zero-voltage condition at the detector can be considered equivalent to a short circuit. Suppose, for example, that the lengths of the "Network Input" and "Network Output" lines were zero. Then $E_1 = E_x$ and $I_2 = I_x$.

The current $I_G$ equals the induced voltage $E_G$ times the admittance of the "G" line, which is the known standard conductance, $Y_o$. That is,

$$I_G = Y_o E_G = Y_o (-j\omega M_G I_L) = Y_o M_G (-j\omega I_L) \quad (18)$$

The current $I_B$ equals the induced voltage $E_B$ times the admittance of the B line, which is the known standard susceptance, $\pm jY_o$. That is,

$$I_B = \pm jY_o E_B = \pm jY_o (-j\omega M_B I_L) = \pm jY_o M_B (-j\omega I_L) \quad (19)$$

The current $I_x$ equals the induced voltage $E_x$ times the transadmittance of the network, $Y_{xx}$. That is,

$$I_x = -Y_{xx} E_x = -Y_{xx}(-j\omega M_x I_L) = -Y_{xx} M_x (-j\omega I_L) \quad (20)$$

When $I_G$, $I_B$, and $I_x$ add up to zero, the common $-j\omega I_L$ term is eliminated, and the basic balance equation of the instrument is obtained:

$$\frac{Y_{xx}}{Y_o} = \frac{M_G}{M_x} \pm j \frac{M_B}{M_x} \quad (21)$$

The above equation is normalized with respect to the characteristic admittance of the line and corresponds to the dial calibration, which is normalized, because impedances, voltage ratios, and current ratios, as well as admittances, must be measured. As indicated above, the instrument actually measures the real and imaginary parts, $G_{xx}/Y_o$ and $B_{xx}/Y_o$, of the normalized transadmittance of the network connected directly between the input and output terminals of the instrument:

$$\frac{G_{xx}}{Y_o} = \frac{M_G}{M_x} = -\text{MULT (A scale reading)} \quad (22)$$

$$\frac{B_{xx}}{Y_o} = \frac{M_B}{M_x} = -\text{MULT (B scale reading)} \quad (23)$$

Since we assumed the connecting line length to be zero, $Y_{21} = Y_{xx}$, $G_{21} = G_{xx}$, and $B_{21} = B_{xx}$.

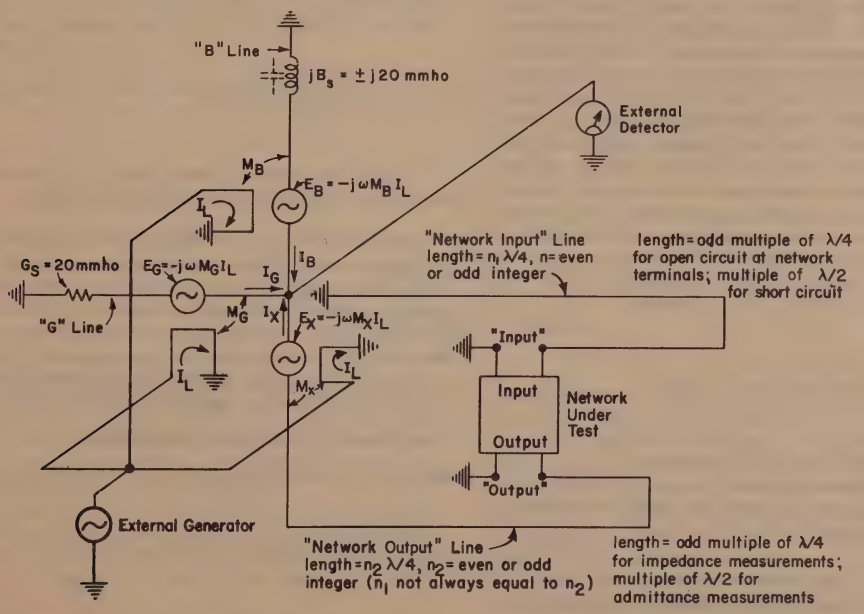



Figure 16b. Schematic Diagram for Immittance Measurements.

The mutual inductance, $M_x$, is the denominator in both the above equations and hence is a common multiplier. The values of the mutual inductances, $M_x$, $M_G$, and $M_B$, depend on the angular position of the loops. The angular position of the G loop can be calibrated directly in normalized transconductance, the B loop in normalized transsusceptance, and the X loop in a common multiplier. These calibrations are independent of frequency and, by virtue of the positive and negative ranges for two of the three loops, permit measurements in all four quadrants of the complex plane. The scale associated with the G loop is labeled the A scale, and is calibrated from 0 to 1.5. The scale associated with the B loop is called the B scale and is calibrated from 0 to ±1.5. The MULTIPLIER is calibrated from ±1 to infinity.

The assumption of zero length of lines between instrument and network cannot be realized in practice, since the effective measurement points are located within the instrument. However, by adjustment of the "Network Input" and "Network Output" lines to odd or even multiples of a quarter wavelength, the instrument can be made to indicate directly the transadmittance, transimpedance, complex transfer current ratio, and complex transfer voltage ratio of networks whose terminals are not the actual measurement terminals of the instrument.

4.4 MEASUREMENT OF TRANSADMITTANCE. To measure the transadmittance of a four-terminal network, we must apply a voltage to one set of its terminals and measure the short-circuit current in the other set. Figure 15B shows this circuit with passive elements, and Figure 15E shows an equivalent circuit more useful for active networks such as vacuum tubes. Note the sign conventions used.

Transadmittance is defined as output current flowing through a short circuit divided by input voltage. The problem of placing the measuring device close enough to both sets of terminals to avoid resonances at vhf and uhf is solved by the adjustable lines in the instrument, which allow the measurement to be made at precisely a half wavelength (or a multiple thereof) from the terminals. When both "Network Input" and "Network Output" lines are adjusted to a half wavelength, the network output terminals are effectively short-circuited, because the half-wave "Network Output" line terminates at the detector junction, which, at null, has zero voltage and can be considered to be a short circuit. The half-wave line produces a similar short circuit at the network terminals and makes $I_2 = I_x$. The input half-wave line makes $E_1 = -E_x$. Therefore

$$\frac{Y_{21}}{Y_o} = \frac{I_2/E_1}{Y_o} = \frac{-I_x/E_x}{Y_o} = \frac{Y_{xx}}{Y_o} = -A - jB \qquad (24)$$

where A and B are the A and B scale readings.

The reverse transadmittance, $Y_{12}$, can be measured by the same procedure, but with input and output connections to the network interchanged.

4.5 MEASUREMENT OF TRANSIMPEDANCE. To measure the transimpedance of a four-terminal network, we must apply a current to one set of its terminals and measure the open-circuit voltage in the other set. Figure 15C shows this circuit with passive elements, and Figure 15D shows an equivalent circuit more useful for active networks. Note the sign conventions used.

To measure transimpedance, which is defined as $E_2/I_1$ with the output of the network open-circuited, both input and output line lengths are set equal to an odd multiple of a quarter wavelength. The quarter-wave output line converts the equivalent short circuit at the detector junction into an open circuit at the network. Also, the output quarter-wave line "inverts" the voltage $E_2$ into a constant times the current $I_x$, and the input quarter-wave line "inverts" the voltage $E_x$ into a constant times the current $I_1$. It can be shown that

$$\frac{Z_{21}}{Z_o} = \frac{E_2/I_1}{Z_o} = \frac{-I_x/E_x}{Y_o} = -A - jB \qquad (25)$$

where $Z_o$ is the characteristic impedance of the coaxial lines, 50 ohms.

Reverse transimpedance, $Z_{12}$, is measured in a similar manner with the input and output connections reversed.

4.6 MEASUREMENT OF TRANSFER CURRENT RATIO. For the measurement of the transfer current ratio of a network with its output terminals short-circuited ($I_2/I_1$), the output line is set to a half wavelength (see Figure 15A for sign convention). The output terminals of the network are effectively short-circuited by the half-wave setting of the output line, which also makes $I_2 = I_x$. The quarter-wave input line makes

$$E_x = \frac{jI_1}{Y_o}, \text{ and therefore}$$

$$\frac{I_2}{I_1} = \frac{-jY_{xx}}{Y_o} = -B + jA \qquad (26)$$

The reverse transfer current ratio, $I_1/I_2$, can be measured with the input and output connections reversed.

4.7 MEASUREMENT OF TRANSFER VOLTAGE RATIO. For the measurement of forward transfer voltage ratio with the network output terminals open-circuited, the output line is adjusted to a quarter wavelength and the input line to a half wavelength (see Figure 15A for sign convention). The output terminals of the network are effectively open-circuited, because the quarter-wave output line "inverts" the equivalent short circuit at the detector junction into an open circuit at the network. Also, because of the quarter-wave output line, $E_2 = \frac{jI_x}{Y_o}$, and because of the half-wave input line, $E_1 = -E_x$. Therefore,

$$\frac{E_2}{E_1} = \frac{jY_{xx}}{Y_o} = B - jA \qquad (27)$$

Reverse transfer voltage ratio, $E_1/E_2$, can be measured with the input and output connections reversed.

**4.8 IMMITTANCE MEASUREMENTS.** When the Immittance Indicator is mounted on the bridge in place of the Transfer-Function Indicator, the instrument becomes the equivalent of the General Radio Type 1602-B Admittance Meter, with the added features of a built-in adjustable line between the unknown and the bridge, biasing provisions, and a second short-circuited adjustable line that can be used to terminate four-terminal networks for measurements of input or output characteristics. In the immittance-bridge circuit (see Figure 16b), three loops are coupled to three coaxial lines, two of which are terminated in a standard conductance and a standard susceptance, and the third coupled to the "Network Output" line instead of to the "Network Input" line as in the Transfer-Function Bridge. In the circuit shown in Figure 16b, the bridge is set up to measure the output immittance of a four-terminal network. To measure network input immittance the network is simply reversed. Note that the lower line, though labeled "Network Output" because of its use during transfer-function measurements, actually drives the network during immittance measurements. The upper line, though labeled "Network Input" because of its use during transfer-function measurements, acts as either a short or open circuit at the other end of the network during immittance measurements and has no other coupling to the circuit except to provide dc bias if required.

For measurements of two-terminal grounded immittances, the unknown network is connected to the lower ("Output") terminals and the upper line ("Network Input") is not used at all.

When the "Network Output" line is set to a half wavelength or to an integral multiple of a half wavelength, the bridge measures admittance. When this line is set to a quarter wavelength or to an odd multiple of a quarter wavelength, the bridge measures impedance. The scales are calibrated in normalized units from 0 to 1, with a multiplier from 1 to $\infty$. The reference for impedance measurements is 50 ohms, and for admittance measurements, 20 mmhos.

**4.9 BIAS CIRCUITS.** In measurements on active networks, dc voltages or currents must be supplied without affecting the rf circuits. The bias circuits of the Type 1607-A are shown in Figure 16c. Built-in blocking capacitors isolate the measurement standards, external detector, and the "Network Input" line. Filter networks, each comprising two chokes and two bypass capacitors, allow insertion of dc voltages and currents and prevent rf leakage. Choke and capacitor ratings impose limits of 2.5 amps and 400 v, although higher currents may be used for short periods. The loading effect of the input filter on the "Network Input" line is negligible, because the filter is near the short-circuited end of the line. The only loading effect of the output filter on the detector line is a slight reduction in detector sensitivity.

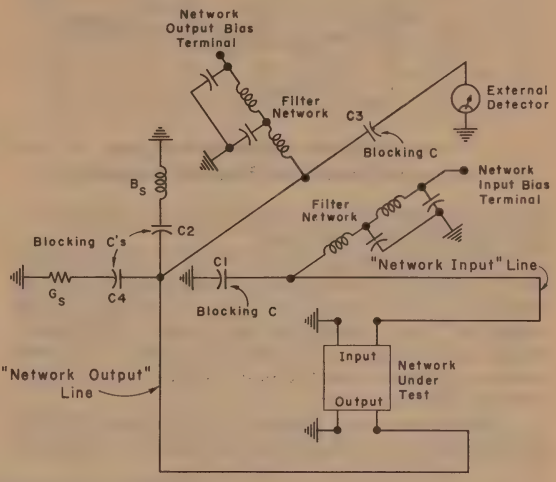



Figure 16c. Schematic diagram of dc bias circuits of the Transfer-Function and Immittance Bridge.

# Section 5
# APPLICATIONS

**5.1 TRANSISTOR MEASUREMENTS.** The most common network representations used for transistors are shown in Figure 15F. All of the transfer parameters indicated in these circuits can be measured directly with the Transfer-Function Bridge at frequencies between 25 and about 1500 Mc.

Since many transistors operate at very low voltage levels, all applied signals should be kept small during the measurements. By the method mentioned in paragraph 2.2, the rf signal level can be held below 5 mv, which has proved a satisfactory limit.

The high-frequency performance of a transistor or of any other component can be greatly affected by the arrangement of the leads used to connect the element in a circuit. For repeatable results, therefore, the mount used to connect the transistor to the measurement circuit must be standardized and must permit short leads. In the Type 1607-P100, 110, and 400 series of transistor mounts, the leads are connected to the measurement terminals at a point about 1/16 inch away from the case. This arrangement is reasonably close to that used in most practical high-frequency transistor circuits.

The $\alpha$-vs-frequency characteristics of an experimental diffused-base, germanium transistor (Bell Telephone Laboratories) in a grounded-base connection are shown in Figure 17.

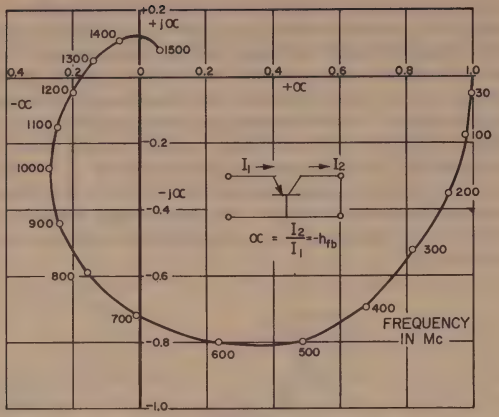



Figure 17. Plot of Alpha vs Frequency for an Experimental High-Frequency Transistor.

This measurement was made with the transistor mounted in a Type 1607-P101 Transistor Mount.

The hybrid feedback factor $h_r$ (= $E_{12}$) can be easily measured by reversal of the coaxial-line connections between the common-base mount and the instrument. The mount is simply rotated 180°, the dc connections are reversed, and the normal voltage-ratio measurement procedure is followed. Under these conditions the input is applied to the collector and the output is obtained from the emitter.

With this instrument, transistors can be measured in either the common-base or common-emitter connection; a complete set of measurements can be made in either connection without calculation of any of the parameters from measurements made in another connection. This factor is important at high frequencies where connection changes can cause changes in the effects of stray capacitances and inductances.

The table below shows a typical set of measurements made on a high-frequency transistor. All the values shown were directly measured with the exception of the $h_o$ parameters. For the $h_o$ measurement the output admittance must be determined with the input open-circuited, a condition easily obtained with the bridge. However, with the open-circuit connection the damping units (refer to paragraph 6.5) cannot be used and in some instances regeneration or oscillation can occur. In these cases $h_o$ can easily be calculated from the formula:

$$h_o = Y_{22} + \frac{h_f h_r}{h_i}$$

The variations in some of the above transistor parameters with collector voltage are plotted in Figure 18. Figure 19 shows the results of measurements of the short-circuit output admittance, $Y_{22}$, on a similar transistor.

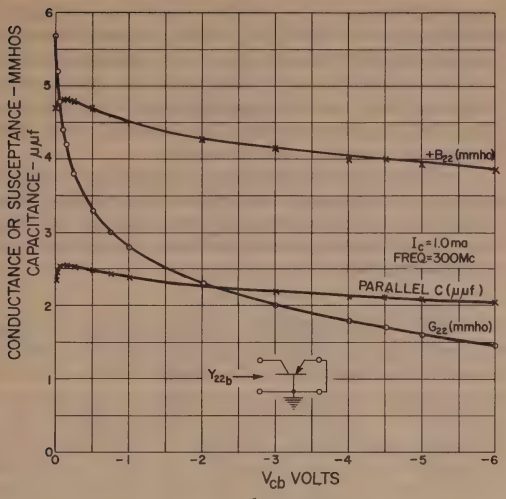
The extrinsic base resistance, $r'_{bb}$, of a transistor is often determined[1] from measurements of the common-emitter input impedance with the collector short-circuited, $h_{ie}$. In this case, the $r'_{bb}$ is approximately equal to the input resistance obtained at a frequency where the reactance is zero. Figure 20 shows a plot of $h_{ie}$ measured on a relatively low-frequency transistor, indicating a base resistance of 27 ohms. At frequencies below the zero reactance point, the reactance becomes positive, owing

[1] R. P. Abraham and R. J. Kirkpatrick, "Transistor Characterization at VHF", *Proceedings of the National Electronics Conference*, 13, pp 385-402, 1957.

## NETWORK PARAMETER MEASUREMENTS ON A HIGH-FREQUENCY TRANSISTOR AT 300 Mc

FREQUENCY = 300 Mc, $V_{cb}$ = -4.5 v, $I_e$ = 1.0 ma, SHELL GROUNDED

| COMMON BASE | | | COMMON EMITTER | | |
|---|---|---|---|---|---|
| | HYBRID | SC ADMITTANCE mmhos | HYBRID | SC ADMITTANCE mmhos | |
| $\alpha_f$ | $h_{fb}$ | $Y_{21b}$ | $h_{fe}$ | $Y_{21e}$ | $\beta_f$ |
| 0.79 - j 0.53 | -0.79 + j 0.53 | -3.4 + j 10.2 | -0.68 - j 1.5 | 2.0 - j 12.0 | -0.68 - j 1.5 |
| $\alpha_r$ | $h_{rb}$ | $Y_{12b}$ | $h_{re}$ | $Y_{12e}$ | $\beta_r$ |
| 0.32 - j 0.18 | 0.04 + j 0.14 | -1.4 - j 1.0 | 0.12 + j 0.09 | -0.4 - j 1.0 | -0.215 - j 0.02 |
| | $h_{ib}$ | $Y_{11b}$ | $h_{ie}$ | $Y_{11e}$ | |
| | 67.0 + j 53.8 ohms | 9.1 - j 6.9 | 115 - j 75 ohms | 5.9 + j 4.1 | |
| | $h_{ob}$ | $Y_{22b}$ | $h_{oe}$ | $Y_{22e}$ | |
| | 0.2 + j 4.25 mmhos | 1.8 + j 4.2 | 3.2 + j 3.0 mmhos | 1.9 + j 4.3 | |



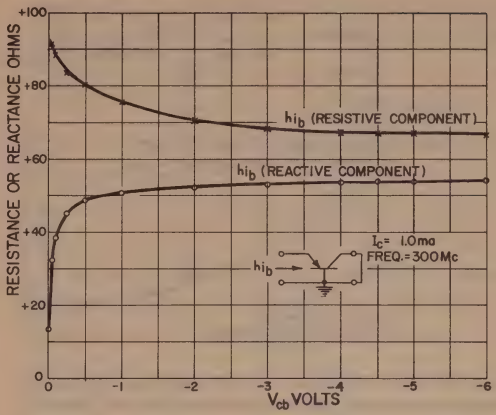
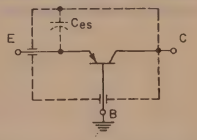




Figure 18. Variation of parameters of a diffused-base transistor as a function of collector voltage.

to the inductance of the leads inside the transistor body and that of the short length of pin between seal and the point where the measurements are made. At much higher frequencies this lead inductance can be in parallel resonance with the stray capacitances to the shell and ground as shown in Figure 20.

In high-frequency transistors, the zero reactance point occurs at a much higher frequency, and the impedance at this point may be affected by the stray lead reactances. A typical measurement is shown in Figure 21. Similar measurements made on a slotted line are plotted on the same figure, and it is evident that they agree very closely with those obtained by use of the Transfer-Function and Immittance Bridge.

In high-power transistors in which the shell is connected to the collector, the measured parameters at high frequencies are significantly affected by the capacitance from the input electrode to the shell. In the common-base connection, this capacitance ($C_{es}$) appears from emitter to collector and is of the order of 1 or 2 picofarads. Current flowing through this capacitance adds vectorially to the current actually flowing through the transistor. At low frequencies the effect is small; however, at very high frequencies (usually around 1000 Mc), the current flowing through the capacitance is



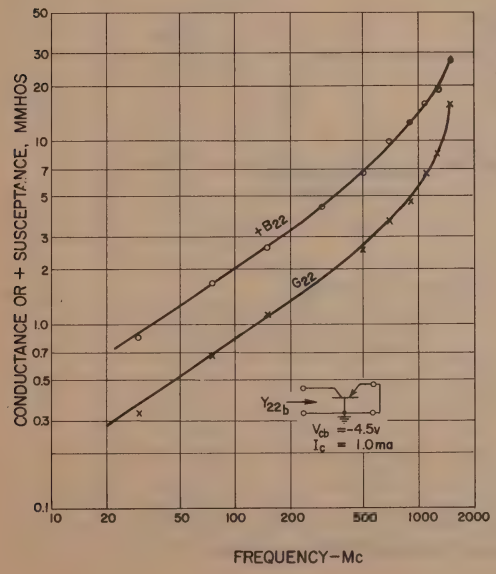




Figure 19. Plot of short-circuit output admittance as a function of frequency for a diffused-base transistor.

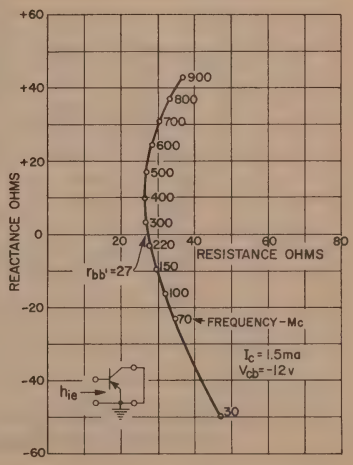



Figure 20. Plot of input reactance versus input resistance, with output short-circuited, for a low-frequency transistor.

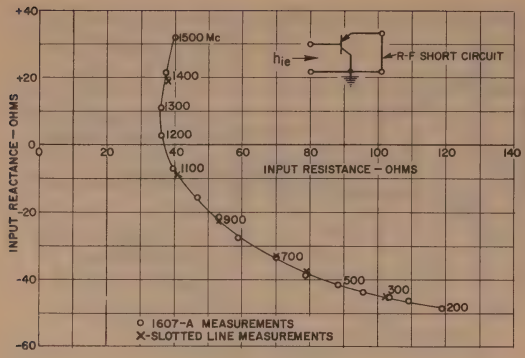



**Figure 21. Input reactance vs input resistance for high-frequency transistor, with output short-circuited. Points measured with a Slotted Line are given for comparison.**

180 degrees out of phase with the current flowing into the emitter, reducing the effective input current, and is in phase with and hence adds arithmetically to the collector current. Under these conditions, the effective transfer-current ratio ($\alpha$) can be larger than unity, and the input impedance relatively high. Although the effect is most pronounced at resonance, it still will cause an increase in the effective $\alpha$ even at much lower frequencies. As a result the true $\alpha$-cutoff frequency cannot be determined solely from measurements of $\alpha$ as a function of frequency.

In the common-emitter connection, the capacitance from the base to shell appears between base and collector. In most cases the $\beta$-cutoff frequency is less affected by the stray capacitance than is the $\alpha$-cutoff frequency.

In either the common-emitter or common-base connection, the measured values are actually those of the device. The increase in $\alpha$ over that expected does not constitute a power gain, as both the input and output impedances are affected so that the apparent increase does not occur.

5.2 TUBE MEASUREMENTS. As with transistors, the mount to connect tubes to the measuring circuit must be carefully designed to give significant and repeatable results. Filters must be provided for heater and screen voltage, although these filters are not as critical as are the filters associated with the input and output circuits. The Type 1607-P201 Tube Mount accommodates seven-pin miniature tubes such as the 6AF4, 6AF4A, 6AN4, 6T4, and other tubes with the same pin connections for grounded-cathode measurements. The measured transadmittance of a 6AF4 in the grounded-cathode connection is plotted in Figure 22. The effective transadmittance first increases with frequency, apparently because of resonance between the grid-cathode capacitance and cathode-lead inductance.

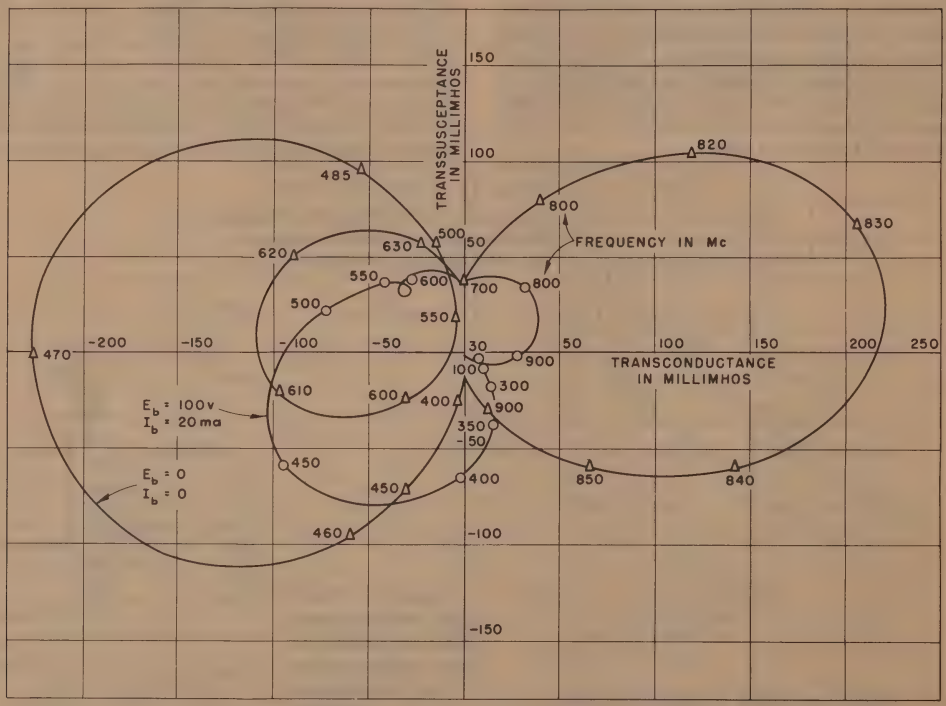



Figure 22. Transadmittance vs Frequency for Grounded-Cathode 6AF4 Vacuum Tube.

At higher frequencies other resonances are apparent, the largest of which is probably caused by the grid-plate capacitance and plate-lead inductance. The large values of transadmittance shown do not cause correspondingly large magnitudes of gain when this tube is used as an amplifier, since the input impedance decreases rapidly as the resonances are approached.

5.3 COAXIAL-COMPONENT MEASUREMENTS. The Transfer-Function and Immittance Bridge can measure the transfer admittance or impedance and attenuation of circuits fitted with coaxial connectors. Figure 23 shows the results of short-circuit current-ratio measurements made on a Type 874-G10 Attenuator Pad, and Figure 24 shows transadmittance of the same pad. Other possible applications are for filters, coupling networks, amplifiers, and other four-terminal coaxial devices. In these measurements, the input and output reference planes must be specified.

5.4 LUMPED-COMPONENT MEASUREMENTS. The direct admittance between the two ungrounded terminals of a circuit or component can easily be measured with the bridge. As shown in Figure 25, the direct admittance measurement of a component with neither end connected to ground is not affected by the impedance between either side of the component and ground. This measurement is very useful for determining the characteristics of floating resistors, rf chokes, capacitance between two ungrounded terminals, and many other three-terminal circuits. Figure 26 shows the direct admittance of one of the chokes used in the dc supply filter of the Transfer-Function and Immittance Bridge.

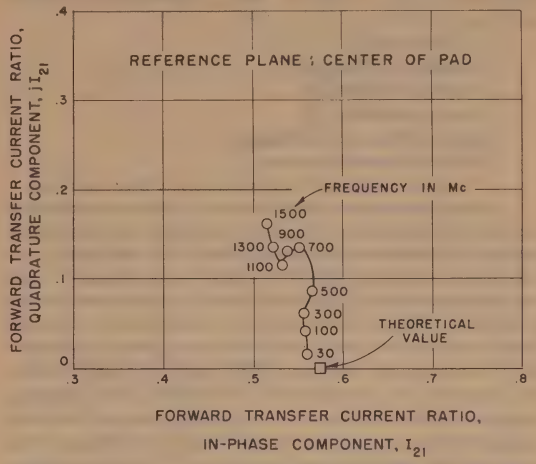



Figure 23. Forward Transfer Current Ratio vs Frequency for a Type 874-G10 Attenuator Pad.

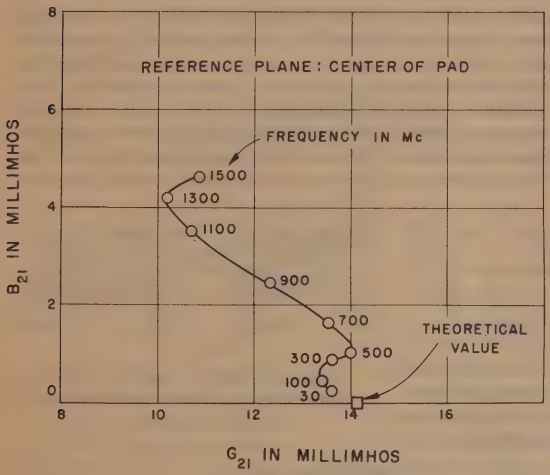



Figure 24. Forward Transadmittance vs Frequency for a Type 874-G10 Attenuator Pad.

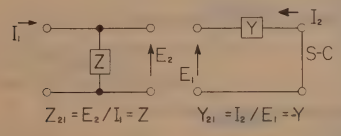



Figure 25. Consideration of Two-Terminal Impedances and Admittances as Four-Terminal Devices.

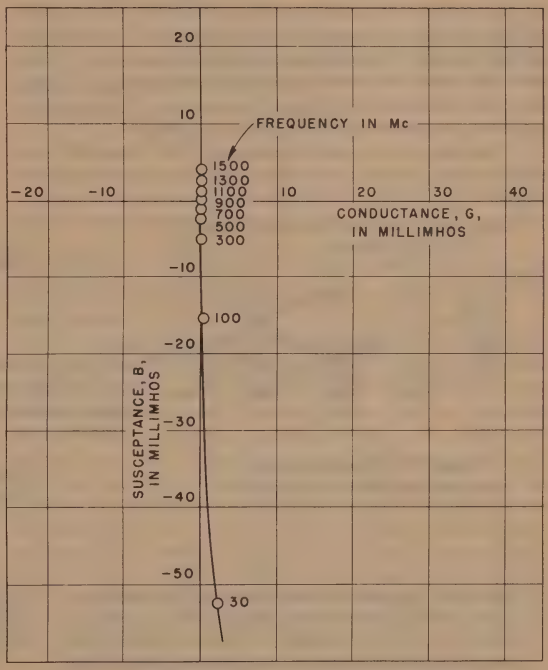



Figure 26. Direct Admittance of DC Supply Filter Choke Used in Type 1607-A.

## 5.5 TUNNEL-DIODE MEASUREMENTS.

5.5.1 GENERAL. The parameters of most tunnel diodes can be measured with the Type 1607-A Bridge over its full frequency range from 25 Mc to 1500 Mc. These parameters include the following:

Capacitance, C
Negative resistance, R
Series inductance, L
Series resistance, $R_s$
Diode self-resonant frequency
Resistive cutoff frequency
Parasitic inductance or capacitance of diode package.

Several precautions are necessary in these measurements because of the negative-resistance, nonlinear, and multivalued current characteristics of tunnel diodes. The well-known current-voltage relation for the diode is shown in Figure 27, and an equivalent circuit is shown in Figure 28. The several modes of operation that can be encountered in tunnel-diode measurements are shown in Figure 29 as a function of circuit resistance, $R_t$. If the dc circuit resistance of $R_t$ is greater than the negative resistance, R, operation will be unstable in the negative resistance region. In Figure 27, $R_t$ is large compared with the negative resistance, and, as the bias voltage is increased, the diode switches from operating point A to B. If the bias voltage is then decreased, the diode switches back from C to D. However, if $R_t$ is lower than the negative resistance, no switching occurs. If the ac circuit resistance of $R_t$ is less than $\frac{L}{RC}$, the circuit oscillates at some frequency determined by the diode and source-circuit parameters. $R_t$ is the sum of the diode resistance $R_s$ and the equivalent source resistance, $R_p'$. The equivalent source resistance is the shunt resistance $R_p$ in parallel with the signal or dc source resistance. The ac and dc source resistances are usually different in practice.

The effective dc source resistance of the Type 1607-A is primarily that of the dc bias supply plus about 4 ohms of series resistance in the bias filter. The high-frequency ac source impedance seen at the diode terminals is of the order of magnitude of 50 ohms at the operating frequency. At other frequencies the impedance will vary but usually will not cause difficulty if a shunt resistor of 50 ohms or less is used in the mount as described below.

The stable region defined by $\frac{L}{RC} < R_t < R$ will vanish if the inductance L is greater than $R^2C$. With most tunnel diodes, package and holder inductance is small enough to permit stable operation. Since low-impedance diodes are necessarily designed with low parasitic inductances, the total circuit inductance between the shunt resistance $R_p$ and the diode must be exceedingly small. This is possible only in carefully designed holders.

A further precaution is required because of the nonlinear diode characteristic and applies to the measurement of any diode. The amplitude of the signal incident on the diode must be small, since small-signal characteristics are generally desired. For the diode characteristic, shown in Figure 27, a value of a few millivolts rms would be considered an upper limit for small-signal measurements. If a superheterodyne null detector is used in the bridge measurements, furthermore, local-oscillator leakage into the tunnel-diode circuit should be kept down to a few millivolts. The trap provided (refer to paragraph 3.1.5) can be used to keep the local-oscillator level below this value.

5.5.2 TEST MOUNTS. A special test mount must be used in measurements on tunnel diodes. The test mount or holder must be carefully designed to eliminate stray inductance and capacitance, particularly if the diode resistance is low. Measurement accuracy is improved if a loading resistor, generally employed to lower the equivalent source impedance, is placed as close to the diode as possible, as shown in Figure 30. This resistance should be noninductive, less than the negative resistance of the diode under test, and should present negligible shunt capacitance. Film-type disk resistors are suitable. The electrical thickness of the resistor should be small compared

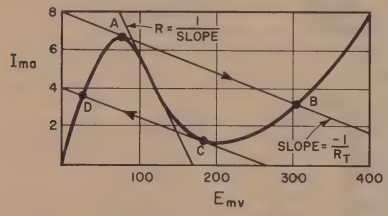



Figure 27. Current-voltage characteristic of a tunnel diode.

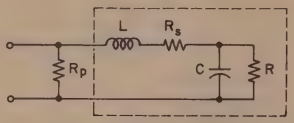



Figure 28. Equivalent circuit of a tunnel diode (inside dotted rectangle), with shunting resistor, $R_P$, which stabilizes operation in a measuring circuit.

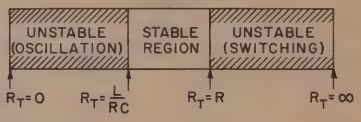



Figure 29. Modes of operation for the tunnel diode as a function of the total circuit resistance, $R_T$.

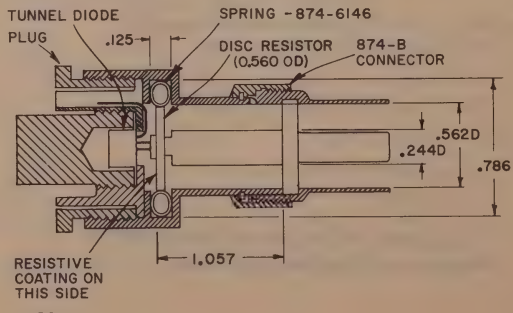



Figure 30. Suggested coaxial mount for connecting a tunnel diode into the measuring circuit. A tunnel diode in the TO-18 package is shown installed in the mount with the ground lead dressed away from the center conductor in a slot provided.

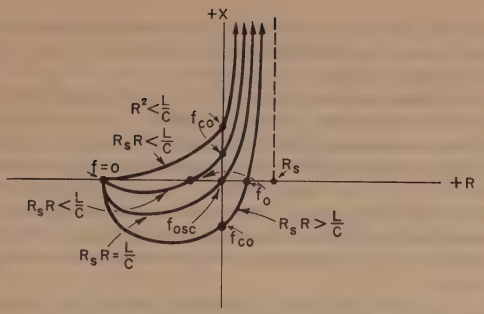



Figure 31. Plot of impedance characteristics as measured to obtain the approximate values for the self-resonant and resistive cutoff frequencies.

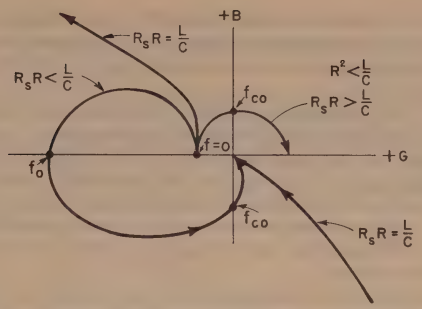



Figure 32. Plot of admittance characteristics for determination of self-resonant and resistive cutoff frequencies.

with the skin depth, so that attenuation through the resistor is negligible at the highest frequency of operation. For convenience the electrical length of the mount shown in Figure 30 is made equal to that of the Type 874-WN3 Short-Circuit Termination.

If a measurement of the diode capacitance and inductance outside of the negative-resistance region is desired, the shunting resistor may be omitted.

5.5.3 DEFINITIONS. The admittance and impedance expressions for the tunnel-diode equivalent circuit shown in Figure 28 are:

Admittance:

$$G_e = -\frac{1}{R}\,\frac{1-\frac{R_s}{R}\left[1+(\omega CR)^2\right]}{\left(1-\omega^2 LC-\frac{R_s}{R}\right)^2+\left(\frac{\omega L}{R}\right)^2\left(1-\frac{R\,R_s\,C}{L}\right)^2} \qquad (28)$$

$$B_e = \omega C\,\frac{1-\frac{L}{CR^2}-\omega^2 LC}{\left(1-\omega^2 LC-\frac{R_s}{R}\right)^2+\left(\frac{\omega L}{R}\right)^2\left(1-\frac{R\,R_s\,C}{L}\right)^2} \qquad (29)$$

Impedance:

$$R_s = R_s - \frac{R}{1+(\omega CR)^2} \qquad (30)$$

$$X_s = \omega\left[L-\frac{R^2C}{1+(\omega CR)^2}\right] \qquad (31)$$

The admittance, impedance, and characteristic-frequency expressions are written for negative-resistance diode operation. The magnitude of the negative resistance should be inserted, therefore.

The characteristic frequencies corresponding to the above expressions are:

Self-Resonant Frequency

Defined for $B_e = 0$ or $X_e = 0$

$$f_o = \frac{1}{2\pi\sqrt{LC}}\sqrt{1-\frac{L}{R^2C}} \qquad (32)$$

Usually defined in the negative-resistance region.

Resistive Cutoff Frequency

Defined for $G_e = 0$ or $R_e = 0$

$$f_{co} = \frac{1}{2\pi RC}\sqrt{\frac{R}{R_s}-1} \qquad (33)$$

Applies only in the negative-resistance region.

Oscillation Frequency

$$f_{osc} = \frac{1}{2\pi\sqrt{LC}}\sqrt{1-\frac{R_s}{R}} \qquad (34)$$

Applies only in the negative-resistance region, and is the frequency at which the short-circuited diode will oscillate, assuming linear diode characteristics.

These frequencies are all equal when

$$R_sR = \frac{L}{C}$$

Typical frequency characteristics are shown in Figures 31 and 32 for the diode operating in the negative-resistance region, and $R^2 < \frac{L}{C}$ except as shown.

5.5.4 MEASUREMENT OF TUNNEL-DIODE EQUIVALENT-CIRCUIT VALUES.

5.5.4.1 General Measurements; Approximate Diode Circuit Values Not Known: For these measurements a special mount must be constructed to reduce parasitic inductance and capacitance in the diode connection to the instrument (refer to paragraph 5.5.2). When the diode circuit values are not known, a measurement of dc voltage-current characteristics will indicate the approximate negative-resistance value; then the correct size of shunting resistor and the proper bias voltage can be determined. The diode admittance or impedance is measured over a frequency range wide enough to yield a rough plot corresponding to those shown in Figures 31 and 32. The approximate self-resonant and resistive cutoff frequencies and the low frequency where the effect of series inductance is negligible are thereby determined.

The procedures described in the following sections are then followed to determine the specific equivalent-circuit values. The data obtained in the above measurements are used to deter-

mine the proper measuring frequencies. The ac negative resistance is also obtained from these data (see Figures 31 and 32), permitting a more accurate determination of the shunting-resistance values.

The admittance of a diode is measured more easily than is its impedance, since the shunt admittance can be simply subtracted from the measured result to yield the diode admittance directly. However, for very low-resistance diodes, more accurate results may be obtained from impedance measurement.

The admittance measurement procedure is as follows:

a. Assemble the tunnel-diode test mount with the shunt resistor installed.

b. Set up the equipment as shown in Figure 33, using the Immittance Indicator. Set the OUTPUT LINE to a half wavelength as described in paragraph 3.1.2.2 except use a Type 874-WN3 Short-Circuit Termination. Refer to paragraphs 3.1.2.5 and 3.1.4 for setting the susceptance standard, and to paragraph 3.1.5 for setting the local-oscillator trap.

c. Plug the diode mount, less diode, into the OUTPUT connector. Adjust the OUTPUT LINE length more accurately by using the shunt resistor in the diode mount as the termination. For this adjustment, set the IMAGINARY arm to zero and balance the instrument by means of the REAL arm and the OUTPUT LINE length, using the smallest possible multiplier. Only a small change in line length should be required. This procedure will provide a satisfactory adjustment only if the shunt resistance is less than about 25 ohms and if the parasitic capacitance and inductance of the shunt resistance assembly are small. Otherwise the standard short-circuit termination or the diode mount with a low-inductance short circuit connected directly across the shunt resistor should be used. The reference plane is therefore at the shunt-resistance location. The bridge is now set up to measure the diode admittance. The signal level at the shunt resistance should be checked to assure that the voltage swing occurs over a linear region of the diode characteristic. For most diodes, this level should not exceed about 2 millivolts. Record the REAL and MULTIPLIER readings, which correspond to the normalized shunt conductance.

d. Install the diode, and adjust the bias to the appropriate value. Since there is a voltage drop in the 4-ohm resistance of the Type 1607-A bias system, a Type 874-T Tee may be installed temporarily between the diode mount and the OUTPUT connector to set the bias, then removed for measurements. When installing the diode, turn off the bias supply to prevent possible diode damage due to discharge of the Type 1607-A bias capacitors through the diode.

e. Balance the bridge with the REAL and IMAGINARY arms, and with the MULTIPLIER arm if required. This yields the normalized conductance and susceptance of the parallel combination of the diode and shunt. To determine the diode admittance from the admittance found in step e, subtract the shunt admittance measured in step c. Make sure that the bias is set to the value that yields the minimum negative resistance. The above procedure is then repeated at other frequencies in the range of interest.

If a multiplier plate is employed, multiply the reading of the arm that the small hole covers (see Figure 7) by one-tenth. The multiplier plate is used to measure very small or very large values of resistance and reactance or of conductance and susceptance with greater accuracy. For further details on the multiplier plate, refer to paragraph 2.6.

When operating at or near the self-resonant frequency of the diode, the total conductance (diode plus shunt) will be generally negative. If the stop in the REAL arm is removed, this arm may be rotated in the negative direction, and if no interference with the IMAGINARY arm occurs, the bridge can be balanced. To obtain the resulting REAL value, transfer the reading, with dividers, to the REAL scale. The frequency range where the conductance becomes negative can be narrowed down if the shunt resistance is reduced, approaching the value $\frac{L}{CR}$. This results in loss of accuracy (because the amount subtracted to obtain the diode admittance is larger) and increases the possibility of oscillation.

5.5.4.2 Measurement of Resistive Cutoff Frequency. At the resistive cutoff frequency, the diode conductance is zero. The procedure outlined above for measuring diode admittance is employed to determine this frequency accurately, the measurements being made in greater detail in the region of expected cutoff frequency. With the shunt resistance installed, the frequency where the measured admittance is identical to the shunt admittance is sought. The best way to find this frequency is to measure the shunting conductance and the diode-plus-shunting conductance at several frequencies in the expected range. Then a graph is made of these two measured values as a function of frequency to smooth the data and to reduce the number of meas-

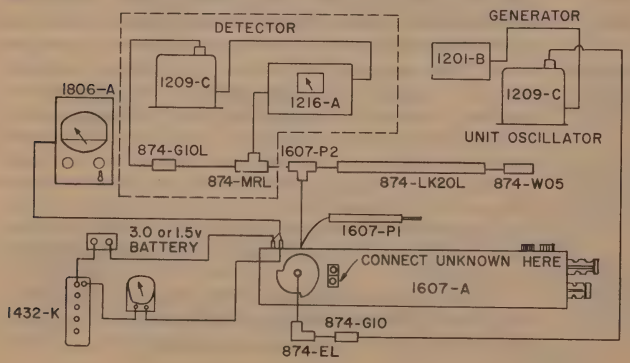



Figure 33. Block diagram of the measuring equipment.

| Type | Item |
|---|---|
| 874-G10 | 10-db Fixed Attenuator |
| 874-EL | Ell |
| 874-LK20L | Constant-Impedance Adjustable Line |
| 874-MRL | Mixer Rectifier |
| 874-WO5 | Open-Circuit Termination |
| 1201-B | Unit Regulated Power Supply |
| 1209-C | Unit Oscillator (250-920 Mc) |
| 1216-A | Unit I-F Amplifier |
| 1432-K | Decade Resistor |
| 1607-A | Transfer-Function and Immittance Bridge |
| 1607-P2 | Tee Assembly |
| 1806-A | Electronic Voltmeter |

urements required. The frequency where the two measured values are equal is the resistive cutoff frequency.

The procedure for measuring the resistive cutoff frequency is the same as that for measuring approximate diode characteristics (refer to paragraph 5.5.4.1). The measurement frequencies will be different, however, in that a greater number of measurement frequencies, all located near the expected frequency, is employed.

In order to improve accuracy, the ac negative resistance or conductance should be measured at a low frequency as a function of bias, as described in paragraph 5.5.4.6, to determine the exact bias voltage required.

5.5.4.3 Measurement of Self-Resonant Frequency. At the self-resonant frequency the diode susceptance or reactance is zero. Since the conductance at this frequency is high, measurement accuracy will be improved if impedance, rather than admittance, is measured. With the shunt resistance installed, the frequency at which the diode reactance is zero is sought. The diode impedance is measured over the region of the expected self-resonant frequency. A graph of reactance as a function of frequency is then made to smooth the data and to reduce the number of measurements required. The procedure is as follows:

a. Determine the exact bias voltage that yields the minimum negative resistance (refer to paragraph 5.5.4.6).

b. Set up the Type 1607-A to measure impedance as follows: Install the susceptance standard and the Immittance Indicator. The setup is shown in Figure 33. Refer to paragraphs 3.1.2.5 and 3.1.4 for setting line length to approximately a quarter wavelength, to paragraph 3.1.3 for setting the susceptance standard, and to paragraph 3.1.5 for using the local-oscillator trap.

c. Plug the Type 874-WN3 Short-Circuit Termination into the OUTPUT connector. The location of the short-circuit should correspond to the reference terminal or plane where the diode parameters are to be measured, and usually corresponds to the location of the shunt resistance. Alternately, a short-circuiting plug can be used in the tunnel-diode mount.

d. Set the MULTIPLIER arm to 1, and the IMAGINARY arm to 0. Then adjust both the OUTPUT LINE and the REAL arm for a null. Only a small change in setting of the OUTPUT LINE should be required.

e. Install the diode mount less diode and measure the shunt impedance by adjusting the REAL, IMAGINARY, and MULTIPLIER arms. Record the settings.

f. Install the diode and adjust the bias to the appropriate value. A Type 874-T Tee may be installed temporarily between the diode mount and the bridge to set this voltage accurately since there is a voltage drop in the Type 1607-A bias system. When installing the diode, turn off the bias supply to prevent possible diode damage due to discharge of the Type 1607-A bias capacitors through the diode.

g. Balance the bridge by adjusting the REAL, IMAGINARY, and MULTIPLIER arms, and record the setting.

h. Repeat this procedure at several frequencies, observing the trend of the imaginary or reactance component through zero. If the shunt has a reactive component, it will be necessary to subtract this reactance vectorially to obtain the diode reactance, as follows:

$$\text{Diode Reactance} = \text{Imaginary Part of } \frac{Z_p Z_m}{Z_p - Z_m}$$

where $Z_p$ = measured shunt impedance

$Z_m$ = measured impedance of shunt and diode in parallel.

5.5.4.4 Inductance Measurement, Back-Bias Method. With the diode biased in the ohmic region, the diode capacitance is essentially short-circuited and inductance can be measured at some convenient frequency. From the diode reactance expression (paragraph 5.5.3) the following equivalent-inductance expression is obtained.

$$L' = L\left[1 - \frac{1}{\omega^2 LC + \frac{L}{CR^2}}\right] \qquad (35)$$

$$= L\left[1 - \frac{1}{\left(\frac{\omega}{\omega_r}\right)^2 + \frac{L}{CR^2}}\right] \cong L \qquad (36)$$

R = diode resistance in the back-bias region

L′ = the inductance value measured.

$$\omega_r = \frac{1}{LC}$$

Since the unknown L is included in the second term in the brackets, it must be small or the error in the approximation will be large. When $\frac{L}{CR^2}$ is large enough (assuming that $\frac{L}{C}$ is known approximately), the choice of the measurement frequency is not critical. In order to reduce this term to 10 percent or less, then at a low frequency $\left(\text{where } \left(\frac{\omega}{\omega_r}\right)^2 << \frac{L}{CR^2}\right)$, R must be less than $0.3\sqrt{\frac{L}{C}}$. This requirement is generally met in most diodes where typical values are $\frac{L}{C} \cong 100$, $R \cong 1$. A nominal low-frequency choice would be about one-fourth the self-resonant frequency, $f_o$.

The measurement procedure is as follows:

a. Assemble the tunnel-diode test mount without the shunting resistance, since operation will be in the positive-resistive region.

b. Set up the Type 1607-A Immittance Bridge to measure impedance as follows:

Install the susceptance standard and the Immittance Indicator, and, if desired, install the multiplier plate for use with the IMAGINARY arm (refer to paragraph 2.6). The setup is shown in Figure 33. The multiplier plate is used to measure very small or very large values of resistance and reactance or conductance and susceptance with greater accuracy. For further details on the multiplier plate, refer to paragraph 2.6. Refer to paragraphs 3.1.2.5 and 3.1.4 for setting line length to approximately a quarter wavelength, to paragraph 3.1.3 for setting the susceptance standard, and to paragraph 3.1.5 for using the local-oscillator trap.

c. Plug the Type 874-WN3 Short-Circuit Termination into the OUTPUT connector. The short-circuit location must correspond to the reference terminal or plane where the diode parameters are to be measured, and usually corresponds to the location of the shunt resistance. Alternately, a short-circuit plug can be employed in the tunnel-diode mount.

d. Set the MULTIPLIER arm to 1, the IMAGINARY arm to 0, and adjust the OUTPUT LINE and the REAL arm for a null. The resultant REAL arm setting will be near zero.

e. Install the diode and adjust bias to the appropriate reverse voltage, monitoring the voltage and current so as not to exceed the rated dissipation. Since there is a voltage drop in the Type 1607-A bias system, a Type 874-T Tee may be installed temporarily between the diode mount and the OUTPUT connector to measure and set the voltage, and then removed for measurements. When installing the diode, turn off the bias supply to prevent possible diode damage as a result of discharge of the Type 1607-A bias capacitors through the diode.

f. Balance the bridge by adjusting the REAL, IMAGINARY, and MULTIPLIER arms.

g. The reactance measured is the diode inductive reactance. The inductance value L is therefore this value divided by $2\pi$ times the measurement frequency. The resistive component measured is approximately the diode resistance $R_s$ if the back resistance is small in comparison.

To check the measured inductance, substitute in the expression for self resonance, with C and R determined.

Inductances can also be measured by a measurement on a dummy diode.

5.5.4.5 Capacitance Measurement. The diode capacitance can be directly measured at a frequency adequately below the self-resonant frequency. This capacitance can usually be measured in either the positive or the negative-resistance region. The frequency and diode resistance limitations are as follows:

From the diode susceptance expression (paragraph 5.5.3):

$$C' = C\,\frac{1-\frac{L}{CR^2}-\omega^2 LC}{\left(1-\omega^2 LC-\frac{R_s}{R}\right)^2+\left(\frac{\omega L}{R}\right)^2\left(1-\frac{R\,R_s\,C}{L}\right)^2} \qquad (37)$$

Where $C'$ = apparent capacitance

The error term should be made near unity, since it contains the unknown. The first step to achieve this is to lower the measurement frequency. If the capacitance is to be measured to within 10 percent, then:

$$f_m << \frac{1}{8\pi\sqrt{LC}} \text{ assuming that } R^2 > \frac{10L}{C}$$

If the capacitance measurement frequency is well below this limit, (but not so low that the capacitance susceptance is comparable to the instrument resolution), then the measured capacitance is:

$$C' = C\left[1-\frac{L}{CR^2}\right] \qquad (38)$$

When $R >> R_s$

It is assumed that the diode circuit parameters are approximately known to permit the frequency choice.

The error term is therefore $\frac{L}{CR^2}$

If accurate measurements are desired in the negative-resistance region, this error term must be small. There is no way to control this error except by deviation from the region where the negative resistance is smallest. In fact, for some diodes it may be necessary to operate nearer the peak and valley regions to obtain sufficient accuracy, as shown in Figure 34. In this figure, representing the low-frequency case, the effect of $R^2$ relative to $\frac{L}{C}$ is shown. The extreme case where $R^2 \leq \frac{L}{C}$ is not

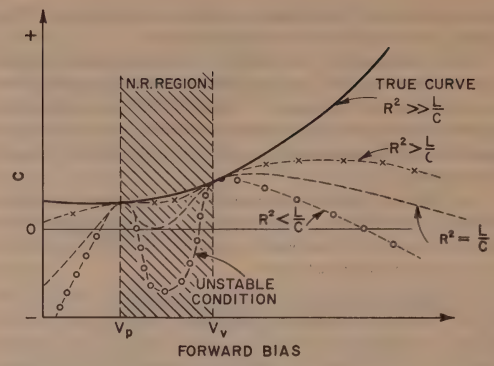



Figure 34. Plot showing how the magnitude of $R^2$ as compared with that of $\frac{L}{C}$ affects the measured values of capacitance.

usually encountered in practical diodes, since this corresponds to the oscillation region overlapping the switching region, where no choice of shunt resistance will yield stable operation.

For a diode where C = 40 pf, L = 3 m$\mu$h, $R_s$ = 1 ohm, and R = 30 ohms, a suitable frequency range is 30 to 70 Mc, and the measurement in the negative-resistance region will not yield an error greater than 10 percent. Generally the condition $\left|R^2\right|_{min} > \frac{10L}{C}$ is not met. In this case operation near the peak and valley points is required.

Measurement of admittance rather than impedance is preferred, since the diode admittance can be obtained from the measured value by simple subtraction. The procedure for measuring capacitive susceptance is identical to that in paragraph 5.5.4.1. In this case the susceptance is measured as a function of forward bias, yielding a result similar to those shown in Figure 34. Unfortunately, the true capacitance versus bias cannot be measured accurately, except in those cases where $R^2 >> \frac{L}{C}$ throughout the bias range.

If measurement in the minimum negative-resistance region is not possible, the average of the values measured at the peak and valley points (where the diode ac resistance is large) is usually reasonably accurate.

Bridge errors due to large changes in conductance can be reduced greatly by measurement of impedance. The improvement of accuracy is achieved in this case at the sacrifice of convenience, as the diode impedance and admittance must be calculated from the measured combination of the shunt and diode impedances.

Alternate Procedure - Impedance Measurement:

For improved accuracy, diode and shunt impedances are measured. The line is set up to a quarter wavelength in this case with a short-circuit termination. The location of the short-circuit is chosen to correspond to the reference plane where the diode parameters are to be measured.

a. Set up the Immittance Bridge to measure impedance as follows:

Install the susceptance standard, the Immittance Indicator, and the multiplier plate in the IMAGINARY arm, following the setup of Figure 33. Refer to paragraphs 3.1.2.5 and 3.1.4 for setting line length to approximately a quarter wavelength, paragraph 3.1.3 for setting the susceptance standard, and to paragraph 3.1.5 for setting the local oscillator trap.

b. Set the MULTIPLIER arm to 1, the IMAGINARY arm to 0, and adjust the OUTPUT LINE and REAL ARM for a null.

c. Install the diode mount less diode and measure the shunt impedance by adjusting the REAL, IMAGINARY, and MULTIPLIER arms. Record the settings.

d. Install the diode and measure the parallel combination of the diode and shunt using the procedure in step c. Record the setting. When installing the diode, turn off the bias supply to prevent possible diode damage owing to discharge of the Type 1607-A bias capacitors through the diode.

e. Reduce the measured settings to resistance and reactance and calculate the diode admittance from:

$$Y_e = \frac{1}{Z_m} - \frac{1}{Z_p} \qquad (39)$$

where $Y_e$ = diode admittance

$Z_m$ = shunt and diode parallel impedance from step d

$Z_p$ = shunt impedance from step c.

A typical measurement of diode admittance vs dc bias voltage is shown in Figure 35.

5.5.4.6 Negative-Resistance or Conductance Measurement. This measurement is usually performed under the same conditions and frequency considerations of capacitance measurement. The measured value reduces to:

$$R' = R - R_s \qquad (40)$$

$R'$ = measured value.

Usually $R_s$ is sufficiently smaller than R so that:

$$R' \cong R$$

The measurement procedure is identical to that used to measure capacitance and approximate diode characteristics (refer to paragraph 5.5.4.1). The diode conductance is measured as a function of bias to determine the minimum value.

5.5.4.7 Series-Resistance Measurement. Either of two procedures may be employed. The first, the resistive-cutoff-frequency method, is reasonably accurate if the negative-resistance and capacitance values are known accurately. The second, the back-bias method, yields an upper limit to this value and is accurate only in some cases since the actual series resistance and the diode back resistance, in series, are measured.

The resistive cutoff frequency is measured as described in paragraph 5.5.4.2. The capacitance C and the negative resistance R are measured as described in paragraphs 5.5.4.5 and 5.5.4.6.

$$R_s = \frac{R}{(R\omega_{c_0}C)^2 + 1} \qquad (41)$$

The resistive-cutoff frequency method of measurement is as follows:

a. Measure the resistive cutoff frequency $f_{G_O}$, capacitance C, and negative resistance R.

b. Calculate $R_s$ from

$$R_s = \frac{R}{(R\omega_{c_0}C)^2 + 1}$$

In the back-bias measurement, it is assumed that the diode impedance reduces to

$$Z_e = (R_s + R) + j\omega L \qquad (42)$$

Therefore, if $R_s$ is much greater than R, then

$$R_s \cong R_s'$$

where $R_s'$ is the measured value

The back-bias procedure is identical to that described in paragraph 5.5.4.4.

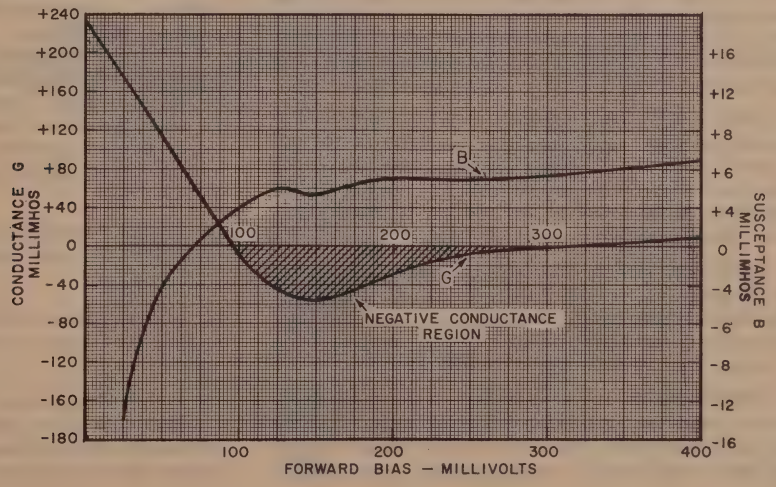



Figure 35. 30-Mc Tunnel Diode Conductance and Susceptance.

# Section 6
# SERVICE AND MAINTENANCE

6.1 GENERAL. The two-year warranty given with every General Radio instrument attests the quality of material and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), requesting a Returned Material Tag. Use of this tag will insure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

6.2 SUSCEPTANCE STANDARD. If the susceptance standard stub (Type 1607-P1) becomes erratic, it can usually be repaired by cleaning. If necessary, increase the spring pressure on the contact fingers. To take the stub apart, unscrew the ¾-inch coupling nut from the base of the Type 874 Connector. Clean the contacts and tubes with a solvent, and relubricate with a light grease or Tycol Oil (Tidewater Associated Oil Co.). The tips of the outer contact fingers should have a diameter of at least 0.575 inch (about 0.010 inch greater than the inside diameter of the tube). If all of the fingers are not sprung out to this diameter, they should be reformed to do so. The inside diameter of the tips of the inner contacts should be sprung into a diameter of 0.238 inch. If they are not, they should be reformed to this dimension.

6.3 INPUT AND OUTPUT LINES. It is not recommended that internal service and maintenance be accomplished on the input and output lines. Their assembly and disassembly are critical operations requiring use of special tools. For best long-life results, keep the lines free of dust and dirt by keeping them closed when they are not in use.

6.4 MEASURING HEADS. The two measuring heads supplied with the bridge are precision devices and should be very carefully guarded against physical damage. In particular, the coupling loops must not be bent from their original positions. To do so would destroy the calibration of the instrument.

6.5 DAMPER UNITS. In measurements on active networks difficulty is sometimes experienced with regeneration or oscillation. Since transmission lines are used to obtain effective short-circuit terminations or zero-impedance sources, the effective source or local impedance may be high at frequencies other than the measurement frequency, and oscillation or regeneration may occur. To eliminate this condition, Type 1607-P500 Damper Units are provided. These units, which can be inserted in the standard mounts, damp out undesired resonances without affecting the desired characteristics. This unit consists of a 50-ohm resistor in series with a dc blocking capacitor that can be connected from either high network terminal to ground. If the damper unit is connected across a terminal whose load impedance is zero[1], it will have no effect on the circuit at the operating frequency. However, at other spurious frequencies where the load impedance may be high and oscillations may occur, the damper unit will reduce the load impedance to not more than 50 ohms resistive, and therefore will usually eliminate difficulties resulting from oscillation and regeneration.

In measurements where the active network is terminated in a short circuit[2], the damper unit should be connected across the short-circuited terminals. In the voltage ratio measurements such as in the measurement of $h_r$, the damper cannot be placed across the open-circuited terminals. In this case, the damper is connected across the source circuit, which has a very low source impedance at the operating frequency and hence will be unaffected by the damping resistor. The damper unit sets an upper limit of 50 ohms on the source impedance, usually low enough to prevent trouble. In the measurement of hybrid output admittance, $h_o$, and of open-circuit impedance, the damper unit cannot be used.

To install the damper unit, remove one of the ¼-inch cap screws located on the side of the mount and screw in the damper unit in its place. There is one cap screw on each side of the mount. Install the damper unit in the section associated with the terminal in question.

The damper will not pass dc, and therefore will not short-circuit the bias.

6.6 TROUBLE-SHOOTING PROCEDURE. The following is a list of the difficulties most likely to be encountered in the

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[1] E. g., the collector circuit in current-gain measurements, or the plate circuit in measurements of transadmittance of vacuum tubes.

[2] E. g., forward or reverse current-gain measurements ($h_f$), input impedance ($h_i$) and admittance measurements with the output short-circuited, and output impedance and admittance measurement with the input short-circuited.

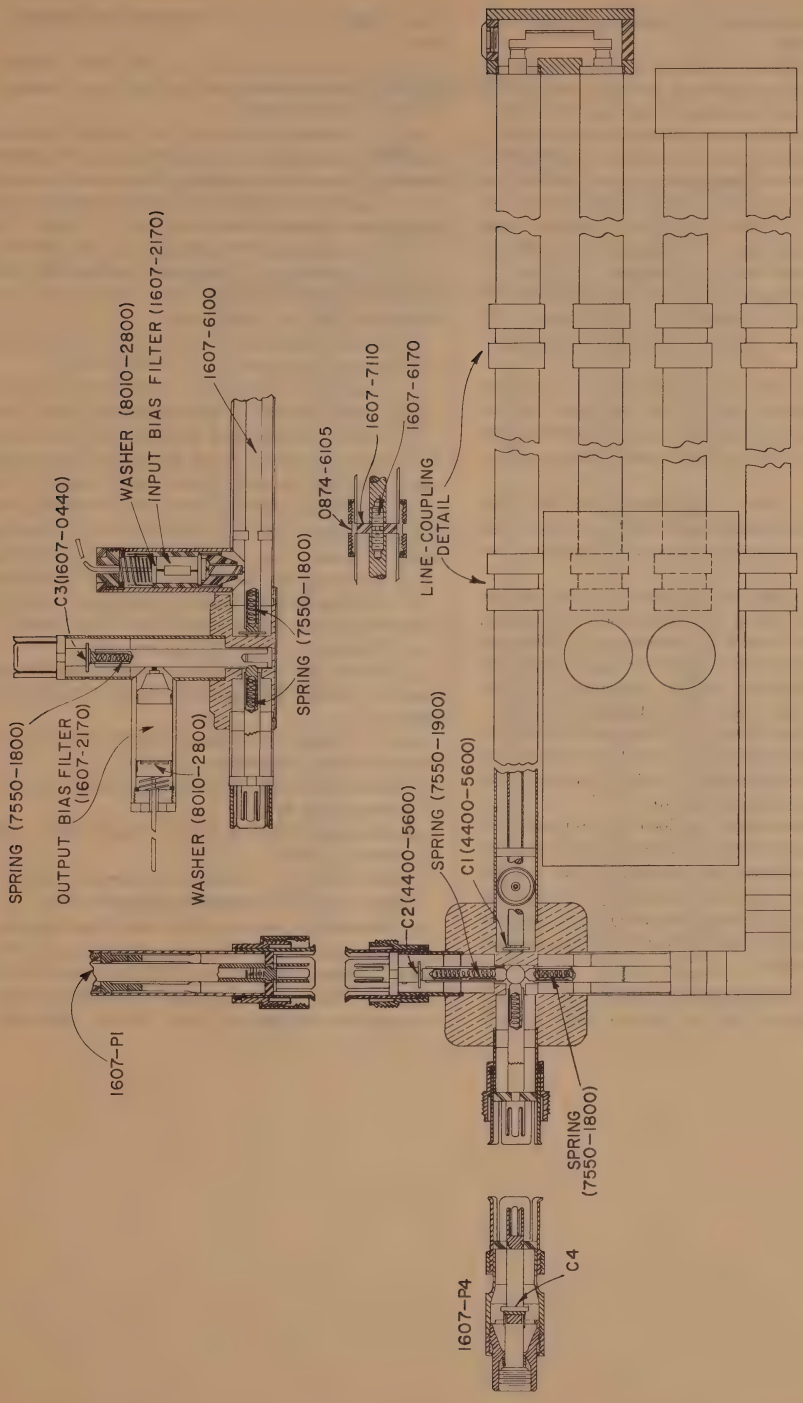



Figure 36. Mechanical Details of the Transfer-Function and Immittance Bridge.

operation of the Transfer-Function and Immittance Bridge, and the probable causes for each.

If the INPUT and OUTPUT LINES are not the same physical length when set to the same electrical length, the MULTIPLIER is not set to ∞, the susceptance stub is not properly set, or wrong terminations are used in setting the line lengths. Differences of up to 1 cm or so in scale readings should not be regarded as abnormal. Another possibility is that blocking capacitor C1 (see Figure 36) is open. Check capacitance as described in paragraph 6.7.1. When removing this capacitor from the line, first remove the input-line bias filter to avoid damage to the capacitor. Check for false null (paragraph 3.1.2.2 e).

If measurements are erratic and not reproducible, the circuits may be oscillating or regenerating. Install damper unit (refer to paragraph 6.5). Also the local or driving oscillator may be squegging.

If the sensitivity is low at low frequencies, remove the pad in the generator lead and increase the coupling in the oscillator to maximum. The fault may also be an improperly tuned local oscillator trap or a local oscillator tuned to beat with a harmonic of the signal.

If the sensitivity is low at high frequencies, the fault may be low mixer current, an incorrectly tuned local oscillator trap, or the local oscillator tuned to beat with a harmonic of the signal.

If a complete null cannot be obtained, the fault may be too large rectified mixer current or a local oscillator beating with the harmonic as well as with the fundamental. (Harmonic difficulties are most likely to occur when the signal frequency is an integral multiple of 30 Mc. Refer to paragraph 2.2 in the operating instructions for the Type 1216-A Unit I-F Amplifier.) The remedy for the latter would be to shift frequencies slightly or add an appropriate Type 874-F Low-Pass Filter. Note that the residual reading due to noise is 10 to 15 divisions on the meter of the Type 1216-A Unit I-F Amplifier.

If no signal is present, either the local or main oscillator may be inoperative. Check the rectified mixer current, then interchange generator and local oscillator connections and recheck the rectified mixer current. Also, the local-oscillator trap may be improperly set or the local oscillator frequency calibration may have shifted. All coupling loops should be set to zero (A, B at zero, MULTIPLIER at ∞).

## 6.7 RESISTANCE AND CAPACITANCE CHECKS.

6.7.1 GENERAL. Capacitors may be checked with a capacitance bridge at 1 kc. For component designations, see Figure 36.

a. C1: Remove the input dc bias filter (refer to paragraph 6.7.2 f). Capacitance across the input-line connector should be 0.0047 $\mu$f +100% -20%.

b. C2: Remove the output-line dc bias filter and the Type 1607-P4 Termination located at the left of the measuring head under the output bias terminals. Capacitance between the center of the susceptance-standard connector and the center of the output-line connector should be 0.0047 $\mu$f +100% -20%.

c. C3: Remove the output-line dc bias filter and the Type 1607-P4 Termination. Capacitance between the center of the detector connector and the center of the output-line connector should be 0.0047 $\mu$f +100% -20%.

d. C4: Capacitance across the connector of the Type 1607-P4 Termination should be 0.0047 $\mu$f +100% -20%.

e. Bias filter capacitors: Capacitance from wire lead to spring finger contacts on each end should be at least 0.0033 $\mu$f.

f. Check for continuity between the center of the output-line connector and the center of the conductance-standard connector (at left of measuring head, under output bias terminals).

g. Check for a dc short across the generator connector.

6.7.2 DC BIAS CIRCUIT. If difficulty is encountered when dc bias is applied to the instrument, check the following:

a. Check that the unit being measured is not shorted or open.

b. Transistor leads should be reasonably short so that they will not touch the inside ground shell of the mount.

c. Check the polarity of bias voltages.

d. Check that the unit under test is not oscillating. Use the Type 1607-P500 Damper Unit (refer to paragraph 6.5 and Appendix 2).

e. The following continuity checks of the bias circuit may be made with an ohmmeter:

Insulated OUTPUT BIAS binding post to center of OUTPUT connector: 4 ohms.

Insulated INPUT BIAS binding post to center of INPUT connector: 4 ohms.

Center of OUTPUT connector to ground: open.

Center of INPUT connector to ground: open.

f. Remove and inspect the dc bias filters, located at the rear of the instrument below the bias terminals, by unscrewing the black bakelite plugs and pulling the units out of the tubes. Check for bent-in spring fingers shorting to the lead joint and for continuity through the filter. Handle these units carefully.

# APPENDIX 1

## TABLE OF VSWR
## REFLECTION COEFFICIENT - VOLTAGE RATIO

| $A_1 - A_2$ db | $\Gamma$ | VSWR | $A_1 - A_2$ db | $\Gamma$ | VSWR |
|---|---|---|---|---|---|
| 1 | .8913 | 17.41 | 17 | .1413 | 1.33 |
| 1.2 | .8710 | 14.50 | 18 | .1259 | 1.29 |
| 1.4 | .8511 | 12.43 | 19 | .1122 | 1.24 |
| 1.6 | .8318 | 10.90 | 20 | .1000 | 1.22 |
| 1.8 | .8128 | 9.66 | 21 | .0891 | 1.194 |
| 2 | .7943 | 8.73 | 22 | .0794 | 1.170 |
| 2.2 | .7762 | 7.94 | 23 | .0708 | 1.153 |
| 2.4 | .7586 | 7.29 | 24 | .0631 | 1.136 |
| 2.6 | .7413 | 6.73 | 25 | .0562 | 1.120 |
| 2.8 | .7244 | 6.26 | 26 | .0501 | 1.105 |
| 3 | .7079 | 5.85 | 27 | .0447 | 1.093 |
| 3.5 | .6683 | 5.03 | 28 | .0398 | 1.083 |
| 4 | .6310 | 4.42 | 29 | .0355 | 1.074 |
| 4.5 | .5957 | 3.95 | 30 | .0316 | 1.066 |
| 5 | .5623 | 3.57 | 31 | .0282 | 1.058 |
| 5.5 | .5309 | 3.26 | 32 | .0251 | 1.051 |
| 6 | .5012 | 3.01 | 33 | .0224 | 1.046 |
| 6.5 | .4732 | 2.80 | 34 | .0200 | 1.041 |
| 7 | .4467 | 2.62 | 35 | .0178 | 1.036 |
| 7.5 | .4217 | 2.46 | 36 | .0158 | 1.032 |
| 8 | .3981 | 2.32 | 37 | .0141 | 1.029 |
| 8.5 | .3758 | 2.20 | 38 | .0126 | 1.027 |
| 9 | .3548 | 2.10 | 39 | .0112 | 1.023 |
| 9.5 | .3350 | 2.01 | 40 | .0100 | 1.020 |
| 10 | .3162 | 1.92 | 42 | .0079 | 1.016 |
| 11 | .2818 | 1.79 | 44 | .0063 | 1.013 |
| 12 | .2512 | 1.67 | 46 | .0051 | 1.010 |
| 13 | .2239 | 1.58 | 48 | .0040 | 1.008 |
| 14 | .1995 | 1.50 | 50 | .0032 | 1.006 |
| 15 | .1778 | 1.43 | 55 | .0018 | 1.004 |
| 16 | .1585 | 1.37 | 60 | .0010 | 1.002 |

# APPENDIX 2

## TYPE 1607 MOUNTS

### TYPES 1607-P101, -P102, -P111, -P401 TRANSISTOR MOUNTS

The Types 1607-P101, -P102, -P111, and -P401 Transistor Mounts were designed for use with the Type 1607-A Transfer-Function and Immittance Bridge for high-frequency measurements on transistors. The essential characteristics of each mount are as follows:

Type 1607-P101: Grounded-base triode, 0.200 in. pin diameter
Type 1607-P102: Grounded-emitter triode, 0.200 in. pin diameter
Type 1607-P111: Grounded-base triode, 0.100 in. pin diameter
Type 1607-P401: Grounded-base tetrode, 0.200 in. pin diameter

In the -P101 and -P111 Mounts, the base is connected directly to ground (common-base connection), and the emitter and collector are connected to the center conductors of two coaxial lines terminated in Type 874 Connectors. In the -P102 Mount, the emitter is connected directly to ground (common-emitter connection), and the base and collectors are connected to the center conductors of the coaxial lines. In the -P401 Mount, one base ($B_1$, see Figure 1) is bypassed directly to ground while base $B_2$ is connected directly to ground. The emitter and collector are connected to the center conductors of coaxial lines. The electrical length of the coaxial line in the mount between either connector and the point of connection to the transistor is the same as the electrical distance between the connector and the open-circuit termination in the Type 874-WO5 or the short-circuit termination in the Type 874-WN5. Holes are provided in all blocks for straightening transistor leads.

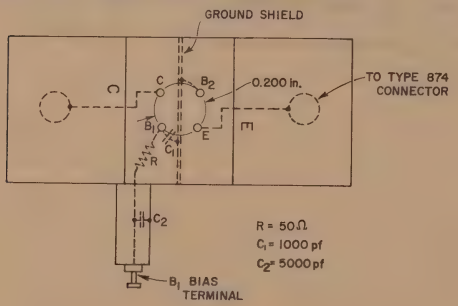



**Figure 1. Type 1607-P401 Grounded-Base Tetrode Transistor Mount**

The -P111 Mount can be used for common-emitter measurements as follows: Bend the transistor leads to fit the appropriate contacts in the mount, leaving a minimum of lead extending above the socket. Use the alignment jig (i.e., the three holes in the body of the mount) to obtain the proper configuration. The additional lead length in such a connection will have some effect on the measurements at higher frequencies, but satisfactory results can generally be obtained up to about 500 Mc.

The -P401 Mount can be used for common-base measurements on transistors having a fourth lead that is connected to the shell of the transistor. The bias terminal should be short-circuited to ground for this measurement. To minimize base-lead inductance, interchange the emitter and collector connections; the base will then be connected to ground directly rather than through a bypass capacitor.

When a transistor is inserted in the mount, contact to the leads is made about 1/16 inch below the top surface of the socket. When the mount is used with the Transfer-Function and Immittance Bridge, all measurements are made with respect to this point.

If the transistor leads are long, they will project below the contacts and add to the measured capacitance. This capacitance with 5/16-inch leads of No. 22 wire is about 0.1 $\mu\mu$f. To determine the exact value, insert a wire of the same diameter and length as the transistor leads and measure its capacitance. The lead length should not be greater than 5/16 inch or the lead may strike the grounded body of the mount. If longer leads are required, holes can be drilled in the block to permit the leads to extend farther, with some effect on the measurement accuracy.

In instances where the collector is connected internally to the shell, the base of the shell must be spaced away from the socket by an insulating washer, preferably of polyfoam or Teflon, to prevent shorting the collector to ground. To determine the shell-to-ground capacitance with the spacer in place, measure the capacitance of a similar transistor with its emitter and base leads clipped off.

Due to a large power gain in some instances, regeneration or oscillation can be a problem. In current-gain measurements with the Type 1607-A, the output circuit of the transistor is terminated in a short circuit at the operating frequency. At other frequencies, however, the load impedance is not zero, and oscillation or regen-

eration sometimes occurs. To eliminate this condition, Type 1607-P500 Damper Units are provided with the mounts. When inserted into the mount, the screw-in unit damps out undesired resonances without significantly affecting desired characteristics. The damper unit consists of a 50-ohm resistor in series with a dc blocking capacitor which can be connected from either transistor terminal to ground. If the damper is connected across a terminal with zero load impedance (such as a collector circuit in forward-current-gain measurements), it will not affect the circuit at the operating frequency. However, at other spurious frequencies where the load impedance may be high with consequent regeneration, the damper unit will reduce the load impedance to no more than 50 ohms resistive, and thus will usually eliminate difficulties resulting from oscillation and regeneration. Oscillation is usually indicated by an inability to obtain a complete null (i.e., to the detector noise level) or by changes in bias currents when a damping unit is installed.

In voltage-ratio measurements, where the device is terminated in an open circuit, the damper can be placed across the terminals of the device to which the voltage is applied, since the effective source impedance at the operating frequency is practically zero.

In impedance or admittance measurements with the transistor terminated in an open circuit, a damper connected across either the effective output or the measurement terminals will affect the measurements. In most $h_o$ measurements, the lack of a damper unit is not important, since the input circuit impedance of transistors is usually low enough to prevent difficulty. It is possible to determine $h_o$ from other measurements. For example,

$$h_o = Y_{22} + \frac{h_r h_f}{h_i}$$

The following table indicates proper damper connections for various transistor measurements.

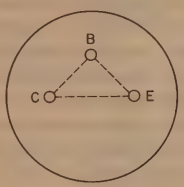
| | 1607-P101, -P111, -P401 Common-Base Connection | 1607-P102, -P111 Common-Emitter Connection |
|---|---|---|
| Measurement | Connect damper to- | Connect damper to |
| $h_f$, $\alpha$, $\beta$, $I_2/I_1$ | Collector | Collector |
| $\alpha_r$, $\beta_r$ | Emitter | Base |
| $h_r$ | Collector | Collector |
| $h_i$ | Collector | Collector |
| $Y_{11}$ | Collector | Collector |
| $Y_{22}$ | Emitter | Base |
| $h_o$ | Neither; see above | Neither; see above |

To install the damper unit, remove one of the 1/4-inch cap screws on the side of the block and screw in the damper unit in its place. There are two cap screws, one for each section of the block; install the damper in the section associated with the regenerative terminal.

The damper unit will not pass dc, and therefore will not short-circuit the bias.

For measurements of $h_o$ and $Y_{22}$ with the Type 1607-A Transfer-Function and Immittance Bridge at frequencies where the admittance is low, use the method described in paragraph 3.2.10 of the Type 1607-A Operating Instructions. For measurements of $h_i$ when the measured impedance is very large, use the method described in paragraph 3.2.9 of the Operating Instructions.

Identification of Terminals.




Transistor terminals on the -P101, -P102, and -P111 Mounts are arranged in the standard manner: that is, at vertices of a right triangle, with the base terminal at the right angle and with the emitter terminal immediately clockwise of the base terminal, as shown.

## APPENDIX 2 (Cont)

### TYPE 1607 MOUNTS

### TYPE 1607-P201 TRIODE TUBE MOUNT

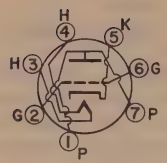



Figure 1. Tube Base Connections for which Mount Is Designed.

**1. DESCRIPTION.** The Type 1607-P201 Triode Tube Mount is designed for measurements on vacuum tubes with base arrangement as shown in Figure 1, in a grounded-cathode connection. Tubes such as the Type 6AF4, 6AF4A, 6AN4, and 6T4 fall into this category.

A Teflon socket is used for low capacitance and reliability. (Available UHF sockets have not been found rugged enough to withstand hard usage.) The cathode terminal is connected directly to ground by means of a very short low-inductance conductor. The plate and grid terminals are connected to 50-ohm transmission lines, which terminate in the Type 874 Connectors marked GRID and PLATE. An internal shield separates the grid and plate circuits. One of the heater terminals is grounded directly at the socket, and the other lead is connected through a 0.4-ohm resistor to a nonresonant feedthrough filter capacitor. A 200-ohm shunt resistor is connected from the ungrounded heater terminal to ground to damp out lead resonances, which can occur with the tube removed from the socket. The two binding posts on the case are the heater connections. The heater voltage applied to the tube is slightly lower than the voltage at the binding posts, because of the voltage drop in the 0.4-ohm resistor.

When the Type 874-WO5 and -WN5 Open- and Short-Circuit Terminations are used for setting or measuring line lengths, the measurements are referred to a plane about 1/16 in. from the base of the socket, as shown in Figure 2. Coaxial transmission lines with constant 50-ohm characteristic impedances are maintained to this point from the Type 874 Connectors. These lines have the same electrical length as that in the short- and open-circuit terminations referred to above. Since, in practice, tubes are usually mounted in a socket, the measurement at this point approximates a practical application and includes the effects of the socket. If measurements with respect to the base of the tube are desired, corrections for the socket can be made by means of the equivalent circuit discussed in Section 4. For some types of measurements corrections can be made easily, while for others the process is very difficult. On the Type 1607-A Transfer-Function Bridge, grid bias can be supplied to the tube through the bias terminals associated with the terminals to which the GRID line is connected. The plate supply can be connected in the same manner.

**2. DAMPER UNITS.** Owing to the large power gain in most vacuum tubes, regeneration or oscillation can be a problem. In transadmittance measurements with the Type 1607-A, the output circuit of the tube terminates in a short circuit, and the input circuit in a zero-impedance voltage source at the operating frequency. However, at other frequencies, the output and input circuit impedances are not zero, and oscillation or regeneration may occur. To eliminate this condition, Type 1607-P500 Damper Units (supplied) can be inserted into the mount to damp out the undesired resonances without affecting the desired characteristics. This damper unit consists of a 50-ohm resistor in series with a d-c blocking capacitor that can be connected from either the grid or the plate terminal to ground. If the damper unit is connected across a terminal whose source or load impedance is zero, it will have no effect on the

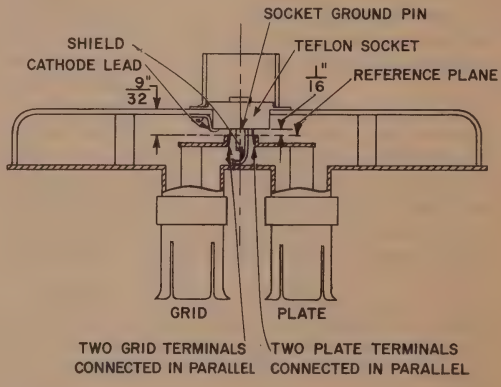



Figure 2. Mechanical Details of Tube Mount.

circuit at the operating frequency. However, at other spurious frequencies, where the circuit impedance is high and regeneration occurs, the damper unit will reduce the load impedance to not more than 50 ohms resistive, and therefore will usually eliminate difficulties resulting from oscillation and regeneration.

To install the damper unit, remove one of the ¼-inch cap screws from the side of the mount and replace it with the damper. The location nearest the GRID connector is associated with the grid line and that nearest the PLATE connector with the plate line. The damper unit will not pass direct current, and therefore will not short out the bias.

For measurement of:

$Y_{21}$ (forward transadmittance)

$Y_{11}$ (grid input admittance with plate circuit short-circuited)

$Z_g$ (grid input impedance with plate circuit short-circuited),

connect the damper in the plate circuit.

For measurements of:

$Y_{12}$ (reverse transadmittance)

$Y_{22}$ (plate output admittance with grid circuit short-circuited)

$Z_p$ (plate output impedance with grid circuit short-circuited),

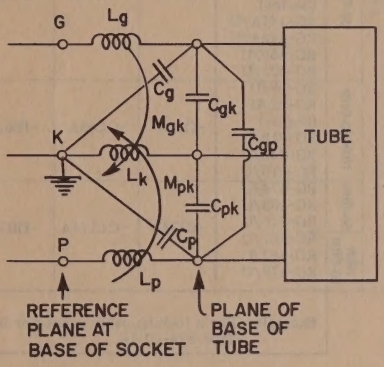
connect the damper in the grid circuit.

**3. SPECIAL CONSIDERATIONS.** For maximum accuracy when measuring small admittances, such as $Y_{22}$, the output admittance of the tube, use the procedure outlined in paragraph 3.2.10 of the Operating Instructions for the Type 1607-A Transfer-Function and Immittance Bridge. If the admittance of the tube alone, less socket, is desired, and the admittance is small compared with 20 millimhos, use the tube mount itself in place of the Type 874-WO5 Open-Circuit Termination to set the line length as outlined in paragraph 3.2.2b(2). The admittance at the tube base will be measured directly under these conditions. This approximation is not valid if the measured admittance is near to or larger than 20 millimhos, since the socket does not exactly form a 50-ohm transmission line.

**4. EQUIVALENT CIRCUIT OF SOCKET.** An approximate equivalent circuit of the socket is shown in Figure 3. In transadmittance measurements, the common inductance in the cathode lead is the most important parameter, followed by the inductances in the cathode, grid, and plate leads. The mutual-inductance couplings are usually negligible.

**5. GROUNDED-GRID CONNECTIONS.** If necessary, this mount can be modified for measurements with a grounded-grid connection as follows:

Remove the cover from the instrument by removing the four screws above and below the GRID and PLATE engraving, respectively. Then unsolder the grid socket terminals from the grid line and solder them to the shield dividing the socket. Then unsolder the cathode terminal from the ground lug and solder it to the bent-down tab at the end of the transmission line. If the leads are kept short, good results can be obtained in this manner.




$L_g$ = 2.6 m$\mu$h  $C_p$ = 1.4 $\mu\mu$f
$L_p$ = 2.5 m$\mu$h  $C_{gk}$ = 0.20 $\mu\mu$f
$L_k$ = 9 m$\mu$h  $C_{pk}$ = 0.008 $\mu\mu$f
$C_g$ = 1.6 $\mu\mu$f  $C_{gp}$ = 0.27 $\mu\mu$f

Figure 3. Equivalent Circuit of Tube Mount.

# TYPE 874 COAXIAL COMPONENTS

## TYPE 874 CABLE CONNECTORS

| APPLICABLE CABLE TYPES | CONNECTOR TYPE | CABLE | CABLE LOCKING | PANEL FLANGED | PANEL LOCKING | PANEL LOCKING RECESSED |
|---|---|---|---|---|---|---|
| 50-OHM | 874-A2 | -CA | -CLA | -PBA | -PLA | -PRLA |
| 50-OHM | RG-8A/U<br>RG-9B/U<br>RG-10A/U<br>RG-87A/U<br>RG-116/U<br>RG-156/U<br>RG-165/U<br>RG-166/U<br>RG-213/U<br>RG-214/U<br>RG-215/U<br>RG-225/U<br>RG-227/U | -C8A | -CL8A | -PB8A | -PL8A | -PRL8A |
| NON-50-OHM | RG-11A/U<br>RG-12A/U<br>RG-13A/U<br>RG-63B/U<br>RG-79B/U<br>RG-89/U<br>RG-144/U<br>RG-146/U<br>RG-149/U<br>RG-216/U | | | | | |
| 50-OHM | 874-A3<br>RG-29/U<br>RG-55/U<br>(Series)<br>RG-58/U<br>(Series)<br>RG-141A/U<br>RG-142A/U<br>RG-159/U<br>RG-223/U | -C58A | -CL58A | -PB58A | -PL58A | -PRL58A |
| NON-50-OHM | RG-59/U<br>RG-62/U<br>(Series)<br>RG-71B/U<br>RG-140/U<br>RG-210/U | -C62A | -CL62A | -PB62A | -PL62A | -PRL62A |
| 50-OHM | RG-174/U<br>RG-188/U<br>RG-316/U | -C174A | -CL174A | -PB174A | -PL174A | -PRL174A |
| NON 50-OHM | RG-161/U<br>RG-187/U<br>RG-179/U | | | | | |

Example: For a locking cable connector for RG-8A/U, order Type 874-CL8A.

## TYPE 874 ADAPTORS

| TO TYPE | | 874- |
|---|---|---|
| BNC | plug | QBJA<br>QBJL* |
| | jack | QBPA |
| C | plug | QCJA<br>QCJL* |
| | jack | QCP |
| HN | plug | QHJA |
| | jack | QHPA |
| LC | plug | QLJA<br>QLPA |
| LT | plug | QLTJ |
| | jack | QLTP |
| Microdot | plug | QMDJ<br>QMDJL* |
| | jack | QMDP |
| N | plug | QNJA<br>QNJL* |
| | jack | QNP |
| SC (Sandia) | plug | QSCJ<br>QSCJL* |
| | jack | QSCP |
| TNC | plug | QTNJ<br>QTNJL* |
| | jack | QTNP |
| UHF | plug | QUJ<br>QUJL* |
| | jack | QUP |
| UHF | 7/8-in. | QU1A |
| 50-Ω | 1-5/8-in. | QU2 |
| Air Line | 3-1/8-in. | QU3A |

*Locking Type 874 Connector.

Example: To connect Type 874 to a Type N jack, order Type 874-QNP.

## CONNECTOR ASSEMBLY TOOLS

| TYPE 874- | FUNCTION |
|---|---|
| TOK | Tool Kit |
| TO58 | Crimping Tool |
| TO8 | Crimping Tool |

## OTHER COAXIAL ELEMENTS

| TYPE 874- | | TYPE 874- | |
|---|---|---|---|
| A2 | 50 Ω cable (low loss) | LR | radiating line |
| A3 | 50 Ω cable | LTL | trombone constant-Z line |
| D20L, D50L | 20-, 50-cm adjustable stubs | ML | component mount |
| EL, EL-L | 90° ell | MB | coupling probe |
| F185L | 185-Mc low-pass filter | MR, MRL | mixer-rectifier |
| F500L | 500-Mc low-pass filter | R20A, R20LA | patch cord, double coax |
| F1000L | 1000-Mc low-pass filter | R22A, R22LA | patch cord, double coax |
| F2000L | 2000-Mc low-pass filter | R33 | patch cord, single coax |
| F4000L | 4000-Mc low-pass filter | R34 | patch cord, single coax |
| G3, G3L | | T, TL | tee |
| G6, G6L | 3-, 6-, 10-, & 20-db attenuators | UBL | balun |
| G10, G10L | | VCL | variable capacitor |
| G20, G20L | | VI | voltmeter indicator |
| GAL | adjustable attenuator | VQ, VQL | voltmeter detector |
| H500L | isolator | VR, VRL | voltmeter rectifier |
| H1000L | isolator | W100 | 100-Ω termination |
| H2000L | isolator | W200 | 200-Ω termination |
| JR | rotary joint | W50, W50L | 50-Ω termination |
| K, KL | coupling capacitor | WN, WN3 | short-circuit terminations |
| L10, L10L | 10-, 20-, & 30-cm rigid air lines | WO, WO3 | open-circuit terminations |
| L20, L20L | | X | insertion unit |
| L30, L30L | | XL | series inductor |
| LAL | 33-58 cm adjustable line | Y | cliplock |
| LK10L, LK20L | constant-Z adjustable lines | Z | stand |

## MISCELLANEOUS COAXIAL CONNECTORS

| CONNECTOR TYPE | TYPE NO. | USED WITH |
|---|---|---|
| Basic | 874-B | 50-ohm Air Line |
| Basic Locking | 874-BL | 50-ohm Air Line |
| Panel Locking | 874-PLT | Wire Lead |
| Panel Locking Recessed | 874-PRLT | Wire Lead |
| Panel Locking Feedthrough | 874-PFL | Type 874 Patch Cords |

L suffix indicates locking Type 874 Connector.

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